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OF

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PAPERS, DISCUSSIONS, ABSTRACTS, PROCEEDINGS

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LXXXVI.

MUNICIPAL ENGINEERING.

By Hon. L. E. McGann.

*An Address.**

Mr. Toastmaster and Gentlemen of the Western Society of Engineers: I must first thank your toastmaster for giving me a cue. It was since I entered the hall this evening that I was informed that I was expected to address you. I congratulated myself when your representative visited me and asked me to attend your banquet that I would have the pleasure of enjoying a banquet with the Western Society of Engineers—many of the members of which it has been my pleasure to meet during my labors throughout the city—without being expected to say anything, especially on municipal engineering. I see by the programme that I am expected to speak on "Municipal Engineering." Had I been advised with, and had your committee insisted that I should speak on any subject at all, I would at least have asked them to change it and make it read "Engineering Municipal Engineers." (Laughter.)

Your toastmaster, however, has suggested another thought that relieves me somewhat and gives me an opportunity to talk shop. Before attempting to do so, however, I wish, like the gentleman who preceded me, to testify to the faithful, zealous, intelligent conduct of the engineers of the city in promoting and protecting her interests. There is no class of men whom it has been my pleasure or my duty to meet of whom I am so ready to testify to their worth, their honesty, their intelligence and their great value in promoting and building up this great city, as of the engineers in connection with this municipality. (Applause.) And I am proud to have the opportunity to say so to the Western Society of Engineers, because I want to ask the members of this society that, in the discussion of the great questions which are now agitating this city, they lend their trained minds as citizens—that they lend their efforts as citizens, to aid in solving many of the problems that to-day must be solved to redeem the city from a position of ridicule before the world.

I am well aware that what I am saying is something that when reported and read abroad may not be creditable, but there are conditions in this city that must be discussed candidly and honestly. We

*Delivered before the Western Society of Engineers at its annual meeting, January 2, 1900.

must not deceive ourselves while we are praising ourselves to the world. The period of deception in this world is past. The facilities of communication and of disseminating information are so great that when we pretend to the world to have virtues and material advantages which we have not, instead of succeeding in imposing on the people of the world, we advertise to them our weakness. And I know of no class of men better fitted by their training, by their profession, by their daily experience of meeting conditions as they are, who are better fitted to discuss and to form plans for the redemption of this city. And while we have been most unfortunate in being led into a condition that requires this, it may, like many other great disasters, in the end prove a blessing. Perhaps the complete destruction of the temporary improvements that were made from time to time in the development of this city would provide an opportunity for the presentation of a broad and completed plan for the building of Chicago on such a scale of perfection that we might say to the world that Chicago is what every citizen desires it to be—the most perfect in every appointment of its municipal improvements, the most desirable to live in, the best city in the world, and providing opportunities for men of all trades and occupations. I say that our present condition may prove a benefit. But, gentlemen, we have arrived and are at a time when it requires not the making of plans for individual improvements. The engineering work to be done in this city should be done with reference to a completed city in every detail—its roads, its walks, its bridges, its water service, its sewer service, and all the ordinary maintenance of the city. All are in such condition as to require the best thoughts of the best minds in this city, and for men of experience, men of training, I know of no body of men that is better equipped to undertake to perform that duty for Chicago that the Western Society of Engineers. (Applause.) If that is so, the duties devolving on you gentlemen as citizens require that you should step outside of the usual lines of employment, and give to this city, which has provided opportunity for so many engineers, at least the benefit of your best thought in formulating plans, in the execution of which certainly many engineers will receive benefit.

I am not fully aware as to the principal purpose of your organization. Most organizations of the kind are called into being for the purpose of promoting the individual welfare, as well as the collective welfare, of the class. The trade unionists, in their way, seek to promote the interests of their particular trade. In commercial life, I find the merchants anxious and eager, doing all in their power to provide opportunity for themselves. Whether it is to the credit or not of your society, I have never known the Western Society of Engineers to agitate or promote sentiment that would give its members opportunity. That may be to your credit, or, rather, it may have been to your credit, and while I do not advocate as a motive in great works that many men receive benefits, there are times when men must receive great benefits in order to secure great advantages

to communities, and we have arrived at such a time in the city of Chicago. I may hope, then, that the Western Society of Engineers will add to the other reasons, the other purposes, of its organization, the promoting of the welfare of its members, if for no other reason than that the city of Chicago may secure the advantage of their efforts.

There is not a question entering into the necessities of the city from an engineering standpoint on which there is not a great difference of opinion, whether it is the construction of a bridge, the building of a sewer, the laying of a pavement or sidewalk, in fact, there is a difference on every question that is presented. There was a period when our center-pier bridges were considered monuments to the administration that had supervision of their construction, and the Mayor and City Engineer and Commissioner of Public Works were all glad to see their names placed on the plates indicating that they had participated in the erection of the structures. The day has come when the center-pier bridge has become a nuisance, an obstruction to navigation and a hindrance to securing the much-desired advantage of pure water. While our Chicago river has been of the greatest advantage in the development of Chicago by the encouragement of commerce, owing to the development of the great vessel transportation of the lakes—a development made necessary by close competition and the necessity to cheapen freight transportation, our center-pier bridges to-day stand as a menace to the future of Chicago. And while many types of bridges have been presented for the consideration of the authorities in Chicago, there is no one type of bridge that has yet been accepted as being entirely satisfactory for the purpose of securing passage over the Chicago river, accommodating transportation and cheapening the cost of operation and maintenance of the bridges. So that in this one line alone there is eminent opportunity for the genius of the engineer.

Without going into detail, the bridge question is to-day one of the most important questions, from an engineering standpoint, as well as a financial standpoint, that the city of Chicago has under consideration. First, because those structures must be changed to permit of the continued use of the river for purposes of navigation. The obstructions placed in the river are continuously driving navigation from the main branch of the Chicago river to another portion of Chicago. And, while it is in Chicago—and no word of mine shall prejudice the development of the section of the Calumet—I still believe that where the great center of our population rests, where millions upon millions of money have been invested with reference to established improvements by the city of Chicago, there rests a moral obligation on this municipality to maintain those conditions without prejudice to these extraordinary investments. (Applause.) To do it will require a proper solution of the question of revenue. That, I believe, like our general physical condition, has been permitted to get into a condition so vile, so unsatisfactory, that the people of this city will find a way to solve it in the very near future.

Then will come the opportunity of the engineer or the engineers to present plans for solving the bridge question.

The question of pavement is one that is agitating Chicago, as it is agitating every city in the world. There is no pavement that has been experimented with in any city—and every pavement appears to be an experiment—that is satisfactory from all standpoints. In our own city we may be following along the line of experience of the older cities of the world. We may be said to-day to be promoting improvements that have been abandoned by the older cities of the world. The reason for it is that we have had no bright, young mind, or older one, to come forward and give us a pavement peculiarly fitted for Chicago. While London and Paris are removing the asphalt pavements, we are now laying them and advocating them. For one, I am not advocating them. In my official capacity I must move along with the demands of the community, because I have nothing better to offer The brick pavements are being presented as a sort of make-shift, a sort of substitute, because it is a little cheaper; that is, the first cost is cheaper.

Recently one great stride has been made in the laying of the pavement, and that is the requirement for a more permanent foundation, and in a recent discussion many public men and citizens who are deeply interested in the pavement question, have expressed a confidence in the Western Society of Engineers as being the proper body to whom to refer the question of the foundation of the pavement. A change was recently made from the use of natural to Portland cement. It increased the cost. The engineers connected with the city recommended the change because of failure to secure success with the original foundations. The wisdom of the step is disputed. Gentlemen connected with the Real Estate Board, and other organizations connected with the public improvements, have referred that question to the Western Society of Engineers. Whether they did so formally, or only in their public utterances and writings, I am not prepared to say. I have never been informed whether the Manufacturers' Association communicated with your society officially or not. I know in one of their meetings they believed it was the proper thing to do, and so expressed themselves.

Referring to the new foundation, or, rather, to the improved and more expensive foundation, brings me to a subject that is all-important, since we are laying these valuable pavements in the business sections. To-day we lay a pavement over a number of gas mains that are defective, that are not sufficient in capacity; over water-mains that were laid years ago when the requirements of this section were not one-tenth of what they are to-day; over sewers that were built for three, four and five-story buildings, where the floor capacity and the demands on them were not one-tenth of what they are to-day. The laying of the pavements over such underground work means only tearing them up in the very near future for the purpose of reconstructing that underground work. With the many interests in that underground work, gas, electricity, water,

sewers, or the various services for which pipes and wires are laid underground, it simply means this: Unless steps are taken in this city to provide a general sub-way system through all the main streets of the business section, it will be almost impossible to harmonize all of these interests so that they may work together to secure a proper consideration of all and promote the placing of permanent pavements in the business section of the city. I regard that as the question of the day, so far as the business portion of Chicago is concerned.

I would say to your toastmaster I may be trenching upon the time of some of the other gentlemen. I did not intend to talk, but I got on my feet and, really, I don't know where to stop.

I would say that this question of a permanent pavement can never be solved until the question of the underground works of Chicago is solved. It is a question that is worthy the attention of every engineer, both as an engineer in his private capacity and as a citizen. Until very recently it was regarded as a dream—many of the boys irreverently called it a "pipe dream"—but a company known as the Illinois Telephone Co., recently asked for the privilege of constructing wires underground. They had permission to excavate the streets for the purpose of placing wires in the ground. When they sought a place in the ground to locate their wires, they could not find it in the ordinary location, and they were compelled to excavate to a greater depth. They asked for and secured permission to construct a tunnel under the streets ,twenty-five feet deep. So far as I am concerned, I must say I reluctantly signed that permit, because I had in mind that the very location secured by that corporation was a space the value of which cannot be estimated by any man living to-day. That should have been preserved by this municipality for a great underground structure that would accommodate every single interest that enters into the streets and which now requires the removal of the pavement to place there. (Applause.)

I say that this is the problem of to-day, so far as the city of Chicago is concerned, and the city of Chicago, gentlemen of the Western Society of Engineers, is of an area of about half a mile or a mile radius from the court-house in the city, or from the business center. The people visiting your city go very seldom into the suburbs. When they come here on business or on pleasure bent, most of their time is put in at the hotels, and they judge of your city by the conditions in its business center, and what they find is a gas company, along a line of street, tearing up pavement recently laid, seeking gas leaks in pipes which were laid in violation of every reasonable rule of the engineer—hurriedly thrown together, joints extremely crooked, put there by a construction company and turned over to the operating company, and the operating company required immediately to begin paying immense sums for maintenance. So I regard that problem as one of the most important.

On the question of drainage and the position taken by the municipality on the work undertaken to secure the benefits to be derived—

the great work that was so eloquently described by the master-mind who directed the work that the city of Chicago has undertaken, that is, the municipality of Chicago has undertaken—the work of diverting the flow of sewage from the lakes to the drainage channel, I would say that I was one of the citizens who believed that work should have been completed by the Sanitary Trustees, they having authority to secure ample funds for the purpose. And before I was placed in an official position, I fought, as far as my voice and vote were concerned, the policy of having the municipality participate in the work of securing pure water for Chicago, believing that it was the intention of the people of the State of Illinois when they chartered the Sanitary District that the Sanitary Trustees should undertake it all; and that the people of that portion of Chicago included in the Sanitary District also intended that the Sanitary Trustees should complete the work. The City Council of the city, however, believed otherwise, and authorized that a commission be appointed to formulate a plan to submit to the municipality for its consideration, approval and adoption which would utilize the canal, constructed at such great expenditure. I believe all the gentlemen constituting that commission were members of this Society of Engineers, except one. The plan submitted by the commission, known as the Pure Water Commission, is to-day being executed, with but few changes, and these changes consisted in enlarging the main conduits to secure the dilution of sewage so that it would not be necessary for the Sanitary Trustees to build conduits parallel to the conduits or sewers being built by the city. And while the cost to the city has been somewhat increased, the municipality recognized that the same citizens pay the bill, and whether they pay the bill at an office in the city hall or at the office of the Sanitary Trustees was not material. So they have proceeded on the plan that the work now being done is auxiliary to the work which has been practically completed by the Sanitary Trustees.

The progress of that work has not been all that we could wish, but the character of the work is everything that could be expected, and the success of the undertaking is assured. So that in the near future, in addition to diverting the flow of sewage that is now deposited in the Chicago river, every sewer emptying directly into Lake Michigan shall have been diverted from the lake and so cease polluting its waters. It will be emptied into the Drainage Canal and carried to the Mississippi.

The detail plans I daresay every engineer as well as most of the citizens of Chicago are familiar with, and it would be a waste of time and of your patience to attempt to describe them to you here. I wish to conclude by first apologizing for trespassing on your time so long, because I did not intend to do so, and then to say again that I believe the Western Society of Engineers, as an association and as individuals, should co-operate with the city of Chicago in seeking to secure for it a condition that is heartily desired by every citizen and which the great majority of the citizens of Chicago are ready

to pay for. There are a few men who object to paying their fair share of the taxes. They succeed by manipulating legislators and by influencing improper levies. But I believe we are near the period when proper means will be provided, and broad and comprehensive plans made and executed, for the completion of all the necessary municipal improvements of Chicago. That means, not only the improvement of the small area in the business section, but the improvement of every highway, of every byway, of every walk, in the city—the erecting of permanent improvements that will stand as a monument to this generation.

There is no reason why we should fall back into the old temporary, mushroom-improvements that we have had here in past years. Your president and the gentleman who preceded him referred to the skull of the early Saint Patrick and the skull of the present Saint Patrick. While the early "Saint Patricks" may have been brilliant—and they certainly were—and while we revere them, even those of us who are laymen and not identified with your profession; while the names of Cregier and Chesbrough will be revered by every citizen of Chicago who knows how broadly they planned and what values they gave to Chicago and what little returns Chicago ever gave to them, there is still an opportunity for a modern "Saint Patrick" to exercise his broad intelligence and to devise plans and to execute them, on a broad, comprehensive scale that will secure in this city the erection and completion of improvements co-extensive with the desires of its citizens, and public improvements which will be a credit to the engineering profession—which will be a credit to the architects who erect our buildings, and not a discredit as is the little rambling shanty, that lasts for a few years and costs more to maintain before it crumbles away than a proper structure would originally have cost.

I say to you those are the broad plans. This is the broad scheme which I believe the Western Society of Engineers should advocate—not necessarily for its own opportunity, but to extend to your fellow citizens a share of the blessings that are given you by your training, by your genius, by the pursuit of your profession, in return for the opportunity given you in this community. I thank you, gentlemen. (Applause.)

LXXXVII.

A DESCRIPTION OF THE OPENING OF THE CHICAGO DRAINAGE CANAL.

By Geo. M. Wisner, M. W. S. E.

January 17, 1900.

Mr. Wisner—Mr. President and Gentlemen of the Western Society of Engineers: My talk this evening will simply be in the nature of telling you what actually occurred, and I do not intend going into the engineering features of the regulating works at all. I presume you are all more or less familiar with them, but at the same time I will be glad to answer any questions that you may ask, if I can.

We arrived at Lockport on the special train, about 11:30 a. m. The night before Mr. L. E. Cooley had got off the train there and made everything ready to let the water go over the bear trap dam. The crest of the dam was scarcely a half inch to an inch above the water surface, and the water in the canal was level with the lake. The visitors and guests and quite an audience that had gathered from the neighboring localities walked along the banks, or rather, upon the wall of the channel, and then they gathered upon the south abutment of the bear trap dam, and after a few remarks by Mr. Boldenweck, in which he introduced Mr. Taylor, chairman of the commission of Gov. Tanner, the commissioner said a few words which none of us could hear on account of the noise of the water which escapes underneath the bear trap dam. The purport of the remarks, I presume, was what we could call a "jolly," about the will of the Chicago people and their persistency in pushing things to a successful end, after which the signal was given by Mr. Beldenweck, I believe in the words, "Let 'er go, Gallagher," and Mr. Cooley, the trustees and Mr. Randolph, turned some circular wheels which controlled the dam, and the dam began to lower. The motion at first was hardly perceptible, and the only way that we could tell that 160 feet of dam was lowering was that at first there was a small ripple over the dam and then a small, thin sheet of water commenced to go over the crest of the dam. After it got started, however, it moved more quickly, until the dam was down to about the depth of 4½ feet below the surface of the water. At that time there was probably, as near as we could get at it roughly, about 300,000 feet of water per minute going over the dam.

After it was down they had about decided to return to the train, and to go back to Chicago, where there were some good things waiting to be eaten, but before going back they again raised the

dam to see how nicely it worked, and it did work like a charm. There was hardly a ripple in the water as the dam came up above the surface and checked the flow. It had probably been flowing about fifteen minutes before it was raised again, and in that time it had lowered the windage basin at the south end about one foot, as near as I could judge by the ice formation on the south end of the channel. After the dam was raised above the water surface, shutting off the water again, they again lowered it, and the water is still flowing, or was at 6 o'clock this evening.

We then proceeded to the train and back to Chicago, where we took dinner. Several speeches were made by the different members of the commission and the Sanitary Board, and Mr. Randolph, urging that this great work should be carried on, making a navigable channel to the Mississippi.

Now the water had been going down the main channel at this time probably about 200,000 cubic feet per minute, and through the river about 240,000 feet per minute, 40,000 feet going down the Illinois and Michigan Canal. The effect upon the Chicago River was noticeable this afternoon, there being quite a current, but the full effect will not be noticeable until to-morrow afternoon. The water was turned in at 11:10 a. m., and the first effect was noticed at Joliet, a mile below, an hour later. About 5 o'clock this afternoon I got a telephone message from there and the water stood four and one-half feet over the dam (which is known as Dam No. 1 and is right in the heart of Joliet), and was rising at the rate of a foot an hour, up to the last hour, when about two inches was all it had raised.

It is rather hard to say when the effect on the Illinois River all along its route will be noticeable, that is, as it will be in the future, but it probably will take about a month's time.

The problem before us now is, that we have to go to work to measure up the amount of water that is passing over the bear trap dam and through the sluice gates. Speaking of the sluice gates, I forgot to mention that they were not raised to-day at all. They were at the time getting the friction rollers in place to raise the gates, and the only way there was of letting the water out of the channel was by means of the bear trap dam, where the flow is about 200,000 cubic feet per minute, with about three and one-half feet of water going over the crest of the dam. As soon as the gates are ready, however, they will be raised and put in use, although the dam can accommodate the full flow of the channel, 360,000 cubic feet per minute, as laid down by the commission.

The further problem is to measure the flow of the Drainage Canal, which you know will not be a difficult thing at any time, but, at the same time, if you take into consideration the variation of the lake level, it becomes a somewhat complicated problem. As you will readily see, the lake will vary a foot in level, and we have got to change the gates below in order not to have too great current

in the Chicago River, and at the same time keep the discharge of the canal up to the 360,000 foot mark.

I have not touched upon the engineering features of the bear trap dam. I had no intention to do so and am not prepared to discuss them this evening, and it would hardly be fitting for me to do so, but I will be glad to answer any question you may wish to ask. I have simply given you a brief outline of what happened, and if I have not told it thoroughly I hope you will pardon me, as I did not have much sleep last night.

DISCUSSION.

Mr. B. E. Grant—I have seen something in the papers about a large amount of leakage in the dam; have you any measurement or estimate of what that amounts to?

Mr. Wisner—There have been some, what you might call mental estimates, without doing any figuring. We always knew there would be some leakage. This dam is operated by the use of counterweights, and by the water pressing underneath the dam, at the down stream edge of the lower leaf, there is a hinge, or system of hinges, to allow the dam to raise or lower, and there is some leakage there. The leakage was simply this water that got into the chamber under the dam and leaked out through the crack, as you might call it; it is a space of about one-half inch. As near as I could estimate there was 3,000 cubic feet a minute leakage there.

Mr. Grant—Then yesterday's paper in estimating it at 15,000 was somewhat mistaken?

Mr. Wisner—I think it is only about 3,000; I should not figure it at much more than that.

Mr. Geo. P. Nichols—Was it noticeable that this accumulation of stagnant water emitted any material odor?

Mr. Wisner—When the water was first let into the main channel, there was about four feet of water in the channel at Lockport. This was from seepage and rain water that had gradually filled up the canal, and the effect of filling up the canal seems to have been to have pushed this clear water that was in the channel—four feet deep at Lockport and running out up this way to near Willow Springs—to the lower end of the channel, so that when we were at the lower end the water was practically clear; it looked as though it was quite drinkable; and in speaking of this I would like to say, as a matter of interest, that this water going over the dam was as beautiful a sight as I have ever seen.

The dam that holds the water back stood about like that, at that elevation (indicating), the crest of the dam and the upstream coming down here along this lower edge; at this downstream leaf the workmen had to walk across a great deal and there had been a small platform laid across horizontally, so it stood about that position (indicating) with reference to the dam. Well, as the water came over the

crest of the dam and rolled down this downstream lead, there was a resistance to the smooth flow, and it struck the platform which was nailed there, and it threw a semi-circular sheet of water into the air, which looked to be about 12 to 15 feet in diameter, and it was really a beautiful sight. I do not know that that is interesting from an engineering stand point. I do not think the bad water of the Chicago River had as yet got down when I was there.

I would say further that we only let about 200,000 cubic feet of water through, as we had been requested by Mr. Schnively of the Illinois & Michigan Canal commission not to let the full amount through there at once, as it would throw such a deluge of impure water into the Illinois River as to have a bad effect on the fish, and for that reason he wanted us to let a small amount through for a time, until a larger part of the sewage had had a chance to run away. We also wanted to take it slow until the works at Joliet, where we constructed a dam, had a chance to be tried, and also the embankments which line the upper basin, so that there would be no chance for a flood, either at Joliet, or further down.

Mr. Grant—With the 300,000 cubic feet of flow what will be the mean velocity at the by-pass?

Mr. Wisner—Perhaps Mr. Eriksen can tell you that; we made a computation, but it has slipped my mind.

Mr. E. T. Eriksen—I think we made it about 2.4 miles per hour.

Mr. Wisner—Inside of a month we hope to have the by-pass at that point open. That is at present the worst part of the river.

The Chair—Mr. Wisner, what is the elevation of the bear trap dam when it is at its lowest position?

Mr. Wisner—I think it is about minus 13. It has a vertical oscillation of 17 feet, and it goes up to high water.

The Chair—High water is about 4 or 5 feet above Chicago datum.

Mr. Wisner—Yes, that makes 12 or 13, as I remember.

A 175-FOOT COUNTER-BALANCED PLATE GIRDER SWING BRIDGE.

DISCUSSION ON PAPERS LXXXIV AND LXXXV.*

January 17, 1900.

A Member—I would like to ask how your speed of opening compares with that of the other swing bridges?

Mr. Reichmann—I think it compares very favorably with any bridge opened in this city; it is swung in about 40 seconds. It would take about a minute to operate the bridge.

Mr. Liljencrantz— If I remember right, the Northwestern Bridge at Kinzie street requires about one minute also.

Mr. Reichmann—Yes, I think that is so.

Mr. Liljencrantz—Electricity is the motive power of that also?

Mr. Reichmann—Yes, it is.

Mr. Liljencrantz—From the point of view that I am more particularly interested in, I will say that though it is a great improvement on the channel as it was before, I think that at some not very distant date many will wish that the bridge could have been moved about 150 to 200 feet eastward, and the channel cut through that land, which channel, forming here an S-curve, is the worst place in the river.

The Chair—That is up there at the Illinois Steel Company's works?

Mr. Liljencrantz—Compared to what the channel ought to be, it is merely a makeshift, but is probably the best that can be done at the present time.

Mr. John C. Bley—From one of the views on the screen the rail lift is shown as operated by an eccentric, but apparently from that view there is no means to provide for the vibration of the eccentric; that is, the rod seems to be fastened rigidly at the upper end, and at the lower end it takes hold of the eccentric on the shaft, and as far as that view is concerned, there is no means by which it could vibrate. I would like to ask also why the eccentric is made so large?

Mr. Reichmann—The hole in the top through which the eccentric passes is considerably larger than the rod, and that allows the motion of the eccentric rod. The reason the eccentric was made so large is on account of the deflection of the bridge when it swings; besides, the rails fit in pockets at their end supports from which they must be lifted.

Mr. Bley—I did not mean the throw of the eccentric, but what you might call the crank pin.

*Paper by A. Reichmann and W. A. Rogers. See pages 481 to 489, Vol. IV, Journal of the Western Society of Engineers.

Mr. Reichmann—It was made so large because the disc is not part of the shaft, but is keyed on the shaft. If it had been made in one piece it would have been considerably smaller. (Mr. Reichmann then explained by means of slide.)

Mr. Bley—The other question was, how you provide for the vibration.

Mr. Reichmann—The hole through which the rod passes is one and one-half inches in diameter, while the rod is one and one-quarter inch. The rail lift is in no way secured to the rail and when the rail is down it clears the rail lift by one-half inch, so the train load never bears on the rail lift.

DESCRIPTION OF THE ELECTRIC MACHINERY OF THE BRIDGE.

By Albert Reichmannn.

At the time the paper was written, the electric machinery had not as yet been installed. This has since been done.

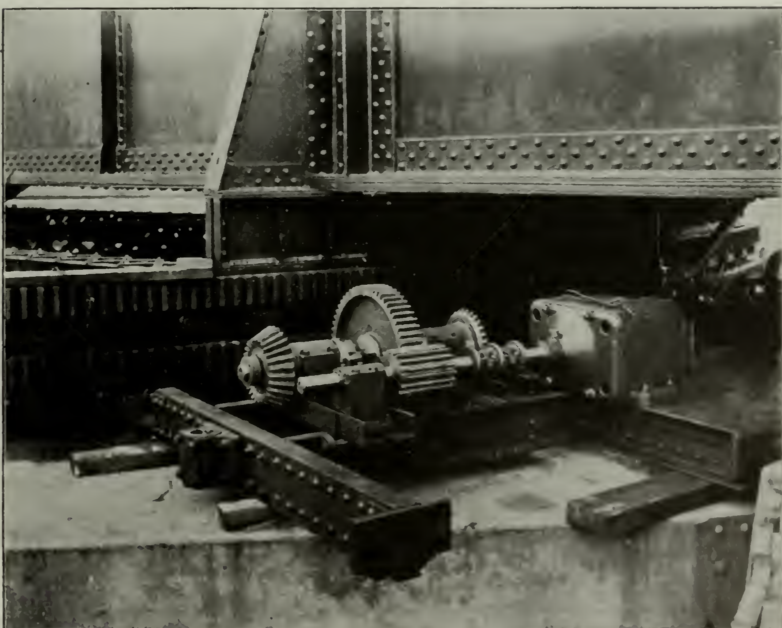


Fig. 1—View of Electric Machinery.

The following tests with the electric motor were made:

Initial voltage, about 500.

Motor light, 484 volts, opening direction, 7 amps. = 4.5 E. H. P. = 3.60 M. H. P.

Motor light, 484 volts, closing direction, 9 amps. = 5.8 E. H. P. = 4.64 M. H. P.

End lifts, 464 volts, 11-12 amps. = 6.8-7.4 E. H. P. = 5.44-5.92 M. H. P.

Bridge starting, 400 volts, 40-45 amps. for an instant.

Bridge accelerated, 400-420 volts, 33-35 amps. 18.6 E. H. P. = 14.88 M. H. P. 3-4 seconds.

Bridge swing, 424-444 volts, 20 amps. = 11.3-11.8 E. H. P. = 9.04-9.44 M. H. P.

Assumed, 80 per cent efficiency for motor.

LXXXVIII.

RAILROAD PRELIMINARY SURVEY BY STADIA.

By John H. Lary, M. W. S. E.

Read February 7, 1900.

While making a preliminary survey for some 200 miles of railway construction, it was desired to make an economical location. The division of the territory, local aid, etc., had some effect on the line, but presented no serious obstacles.

The first difficulty encountered was securing the necessary information regarding the prospective operation of the road, particularly the weight and number of the trains. This was overcome by using data from other roads running through similar territory. Another difficulty was to reduce Wellington's theory to forms that could be intelligently and quickly applied in the field. This was accomplished by substituting known quantities for the particular line in question, using Mr. McHenry's instructions to engineers on the Northern Pacific line.

The last and most serious problem was to obtain the necessary data in the field, to determine the economic line within the time allowed, and within a cost of survey that would be considered reasonable or even allowable.

At first we endeavored to make surveys complete with a regular transit and level party or a two-instrument survey. The country was easy; in fact, there were a great many possible lines.

Stadia surveys were considered, and we concluded that very accurate stadia lines would cost nearly as much as a two-instrument survey. Therefore, we ran at least one two-instrument survey over the entire line, then after a careful reconnaissance of all places in doubt, all lines that appeared favorable were investigated by a very rough and rapid stadia survey.

During the early progress of the work with the assistance of Messrs. F. E. and O. E. Stanley, the stadia work was reduced to a system that is original in many respects. The instrument used was an ordinary theodolite, with stadia wires and vertical arc. I think larger ground levels, and larger vertical arcs, would have been an improvement.

We had a solid combined rod and flag pole made, ten feet long and shod with a point, for setting tacks, also to stick in the ground and be left standing. While the man at the instrument was taking observations the rodman was taking the topography.

As 600 feet is about the limit of sight for a Philadelphia rod, we divided the rod to 0.02 of a foot, and succeeded in reading it to 0.01

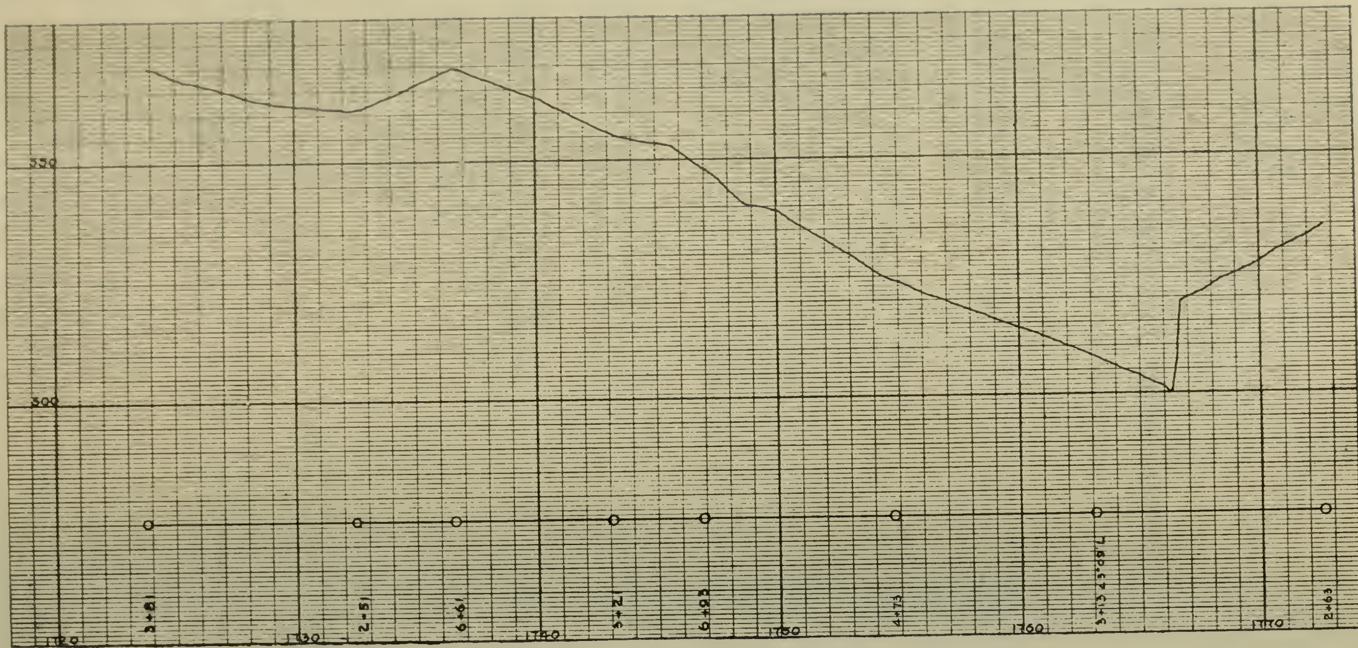


Fig. 1—Profile.

from 1,000 feet to one-fourth of a mile away. Each 0.1 of a foot is in the form of a <, the even points one way, the odd the other, with the 0.5 mark a little more prominent than the other. The characters marking the feet are the same on each side of the center or 5-foot mark. These were designed to be as plain and unlike each other as possible, and to preserve the 0.02 divisions.

The rod was ten feet long for convenience in handling, because the height of the instrument is nearly five feet, or the middle of the rod, and because the decimal divisions facilitate reading the rod from either end or from the middle.

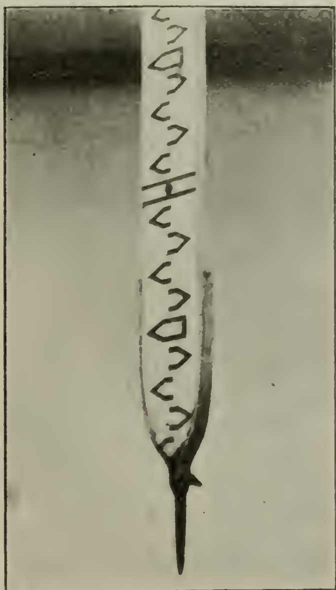


Fig. 2—The Rod.

We ran the survey to make a continuous profile of the line and took the necessary side readings to show the topography.

In starting the survey we assumed a base line, preferably north and south, then read the azimuth of some fixed line, and also read the azimuth of each point of observation. When setting the instrument over a hub the course of procedure was to clamp the vernier where it was when the hub was set, transit the telescope and set on the last instrument hub.

Observations were taken once only, the rodman leaving a lath at each hub, to mark the point and to be used as a back-sight.

The focal distance of the instrument and the vertical angle correction were eliminated except in special cases or with large angles. The vertical distance was taken direct with the telescope level, or

the vertical angle recorded, and the vertical distance taken from a table of natural sines, with two decimals marked off. As the angles were all small, the table was carried on a card in a note book.

All instrument points were numbered successively, and marked as such. Intermediate and side readings were numbered after each instrument point. The elevation of each hub is the algebraic sum of the vertical distances between the hubs, and the intermediate elevations were filled in later from their respective hubs. The sum distance between hubs gives the profile stations, and the stations of the intermediate readings on the line are filled in. The nature of the grade-line can be seen at any time in the field by inspecting the notes, and the profile of the day's work can be easily made in the evening.

The topography is taken by the rodman. He takes the contour notes directly from observation with the land level, + for up, and

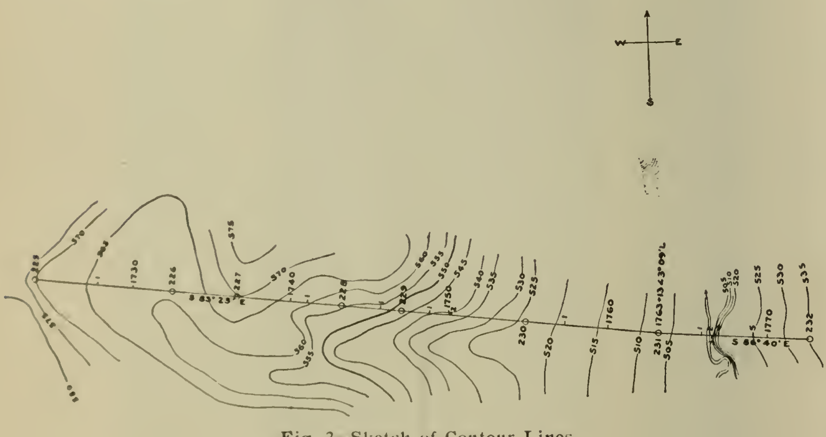


Fig. 3 Sketch of Contour Lines.

— for down. His notes show the horizontal distance for the successive five-foot contours. These can be taken at right angles to the line run in the same way as a regular preliminary or they can be taken with the points of a compass, north, east, south and west.

In platting these notes the line is drawn for the assumed meridian, and all angles are platted from that line. The line is platted from hub to hub, and all intermediate and side readings are afterwards filled in from each hub point. The elevation of all points is marked on the plat and contours, and then platted from the rodman's notes by the use of a table, or preferably with the slide rule. As the horizontal distance from the point of the nearest contour is the total distance between contours, dividing by 5 and multiplying by the vertical distance from the point to the contour sought, the result can be read directly from the slide rule by using 5 as one index.

In running each survey a party of two can run from four to eight

miles of survey per day in a prairie country. A third man can put in his time to good advantage examining the adjacent territory, sketching water courses and investigating the drainage.

Two men can check the notes and make the profile in the evening. One draughtsman will require about as much time for platting as a party for taking the notes, as it is a little more work than platting ordinary preliminary where topography is taken. A stadia line including maps and profiles will cost from 40 per cent to 50 per cent as much as ordinary preliminary. I do not think the stadia could be used economically in a great many cases, especially in connection with the two-instrument survey.

I do not think that the road is now built on the economic line, but I know of nearly 50 miles on the stadia line surveys that are considerably better than the first preliminary, and that in several places where the country did not seem favorable enough to warrant the expenditure of another two-instrument survey.

We also ran about 50 miles of stadia line in the winter, using spikes for hubs, when the ground was frozen so hard that stakes could not be driven. We also ran a stadia survey through a section of country where we did not wish to create any excitement—in fact, it was desired to run it strictly on the quiet—and the stadia proved a perfect success.

DISCUSSION.

The Chair—Mr. Keating has had considerable experience in stadia work within the last few years in connection with the Sanitary District. Perhaps he can give us some pointers on that class of work.

Mr. L. A. Nichols—Do I understand from the paper that the writer said that he only needed two men on stadia work?

The Secretary—(Reading from the paper). A party of two can run from four to eight miles of survey per day.

Mr. Nichols—In taking stadia lines you would have to have a man to sight the instrument or take the rod and have one back to set the stakes. In either case it would require a third man to set the stakes. I have run a great many stadia lines and have always had four men on the work, and eight miles a day is about all the stadia work we could do. I do not see how he could get along with two men.

The Chair—How many men did you have on the sanitary work, the stadia work?

Mr. Keating—We had from six to eight men on most of the work. It was right here in the city and we really needed a large party, at least five or six, because it requires one or two to keep the instrument from being stolen. I do not see how a man could get along on stadia work with two men. I should think three would be the least. I have run a railroad line with one other man, but I had to run up to a point and then back to the instrument. Here in the

city, on stadia work—it was not properly stadia work—we always put in points enough so that we could get in everything, that is, all the corners at least, and we used stadia boards. The difference was not a matter of moment, whether it was a foot or two out or not. I have run lines by stadia and in that we always checked the distances from one hub to another. We used to do that very closely. We ran sometimes a mile where the distance would come within half a foot or, when checked with a steel tape, within a foot or two, and those sites would probably never vary over three or four hundred feet.

ELECTRICAL UNDERGROUND CONSTRUCTION.

DISCUSSION ON PAPER LXXXI.*

February 7, 1900.

Mr. Bley—I would like to ask Mr. Springer what he thinks of the feasibility of building a tunnel continuously with the street in which to put electric wires in common with other lines of work? Is such a plan feasible and what would seem to be the best means of carrying it out?

Mr. Springer—The matter of building a tunnel under the streets to include electric wires as well as all other classes of underground work was touched upon to some extent in the former discussion which followed the reading of the paper and will be found on pages 445 to 449, Vol. IV., of the Journal.

I would say further, however, in reply to Mr. Bley's question, that the building of one or more tunnels of sufficient depth so as not to interfere with existing underground construction and eventually to serve the purposes of the same would, in my opinion, be entirely feasible.

As to the best means of carrying out such a scheme, that is quite a problem and should have considerable study for proper solution. There are two general propositions which might be made:

1. The city could build one large tunnel of sufficient capacity to include the sewage and the water pipes as well as providing room for gas pipes, telephone, telegraph and electric light wires, or,

2. The various corporations could build a tunnel collectively, or several tunnels individually, for the accommodation of their particular kinds of underground installation.

In regard to the first method of solving this problem, we have quite a number of precedents to refer to, as large sewers or tunnels have been built for years in several European cities, among them being Paris and Berlin.

The building of tunnels in the streets by private corporations is of more recent origin. A tunnel now being built in this city by the Illinois Telephone and Telegraph Company was briefly described in the previous discussion on page 449, Vol. IV. This tunnel is very good for the parties building it, but if it became necessary for other companies to do likewise, a large and unnecessary expense would become involved, as well as the necessity for subsequent tunnels to be built excessively deep in order to avoid

*Paper by Geo. B. Springer. See page 401, Vol. IV, Journal of the Western Society of Engineers.

previous ones at street intersections. Whether the Illinois company has made a false start or not remains to be seen, but it seems that the proper solution of the question would be the building of one large tunnel by the city.

Such a proposition has been brought up in the city council twice at least, I think, in the past two years, but nothing has been done as yet. If the city does not want to undertake the building of a tunnel the next best thing would be for the various corporations to build one large tunnel together for the uses of all their underground installation. It would seem that a separate corporation might even launch such an enterprise successfully and rent space to the various companies.

These and various other methods might be suggested for the solution of this perplexing problem, but certain it is that its solution will come, for the tearing up of the streets in the central portion of the city is becoming an increasing and serious source of inconvenience and expense to the general public and companies as well.

The building of a tunnel by any of the methods above suggested would, I believe, be feasible and practicable both from an engineering and financial standpoint.

Mr. Ziesing—I would like to ask how the Illinois Telephone and Telegraph Company would connect with the buildings; that is, in what way would they make the connection from the tunnel to the different buildings?

Mr. Springer—That is something the details of which I am not very well posted upon, but I should think the connection could be made in several ways. I believe there are to be four or five main shafts about 2,000 feet apart, more or less, for construction purposes. Between these, smaller shafts might be built near or inside of the curb walls in the space under the sidewalk and the service cables then be brought up these shafts into that space, thence running along under the walks from building to building; or another method would be to bore holes large enough to drive iron pipes 2 or 3 inches in diameter through from the main tunnel into the space inside the area walls under the sidewalks. One or more of these pipes could be run to each building as needed where subscribers were to be supplied.

Mr. Bley—How deep is this conduit being built?

Mr. Springer—The tunnel is 33 feet below the surface of the street, that is, to the bottom of it. It is 25 feet to the top and the height inside is 7 feet, the walls being about 1 foot in thickness.

DISCHARGE MEASUREMENT OF THE NIAGARA RIVER AT BUFFALO, N. Y.

DISCUSSION ON PAPER LXXXIII.*

December 20, 1899.

Mr. L. E. Cooley: I would like to ask Mr. Stewart how the figure on the Buffalo gauge corresponds with the figure on the Cleveland gauge. He makes a correction there of 0.3. It was not entirely clear to me.

Mr. Stewart—Comparison of the zeros of the gauges at Cleveland and Buffalo were obtained by the method of transferring by water levels. A period of 10 years has been used and gauge readings limited to the months of June, July and August, so as to eliminate effect from wind. The results of the comparison seemed to show that the elevations determined from the Cleveland gauge are 0.3 ft. too high. This correction has been made in table X, column m, giving elevations of the lake at Cleveland.

Prof. J. B. Johnson: I do not often get a chance to discuss a paper before this Society, so I will embrace the opportunity now. I want to say that I consider this paper a model of its kind. It seems to me to give everything that an engineer would want to know about the work, in the shortest possible space, and in very clear, succinct language. I think Mr. Stewart deserves considerable credit for having put it so clearly, so briefly, and yet so fully.

In reviewing the diagrams I see that some of these erratic vertical curves come directly over the sunken caisson, that is, two of the vertical curves in the 6th span correspond to the right and left sides of the sunken caisson, and evidently the other erratic vertical curve corresponds to some obstruction in the bottom, not shown on the profile.

Concerning the high value of *n* found here for Kutter's formula, and which has always to be taken for natural channels, I doubt if wetted perimeter itself either in width and length, or in character of surface, has very much to do directly with the resistance to flow. For a great while I have been impressed with the fact that the resistance to flow is almost wholly made up of the resistance to internal motion, or what you might call the internal work of the water. It is the churning up of the water that uses up the head, and not the resistance to anything on the wetted surface.

I was further impressed with this fact as the result of the work which my friend, Mr. Seddon, brought out in St. Louis, at the Academy of Science, about a year ago. Mr. Seddon is here to speak

*A paper by Mr. Clinton B. Stewart. See page 450, Vol. V, Journal of the Western Society of Engineers.

for himself, but he undertook to show what would be a fair measure of the resistance to flow on the ordinary theory of parallel flow, that is, if the water flows in parellel filaments, that there is very little friction, either on the wetted surface or between the filaments themselves, and that this amount of resistance to flow was a very small proportion, I think 1-100 of one per cent. of the total resistance to flow as measured by the fall or the slope. Well, now, I am satisfied that if those figures are not quite right, they are at least qualitatively right, that is, the resistance to flow is measured in a very small degree by the wetted perimeter, or by the character of the surface *directly*. I put emphasis on the word, directly. The character of the surface does determine the amount of internal motion of the water, and so it becomes an indirect cause of resistance to flow. But it is the churning up of the water that uses up the hydraulic head, and not the frictional resistance of the wetted perimeter.

Now there is in the Niagara River a very irregular bottom, full of rocks and irregularities, so that the water is in continual boil, as the Mississippi River water is, and in all rivers flowing in alluvial beds. These streams provide their own extraordinary resistance, moving the sand into ridges on the bottom, called sand waves, and then the water goes tumbling over these sand waves, these having a gradual slope on the up-stream side and a sudden drop on the down-stream side, and the water goes tumbling over these falls and so uses up its energy. The water is filled with boils and eddies, and that is where the head is lost.

Engineers should learn this lesson. We have had a notable instance of oversight in this sort of thing in some errors that were made in computing the flow of the four-foot steel conduit that most of you know something about, some years ago, down East. There the whole trouble arose from neglecting to take account of the internal motion due to the rivet heads and to the lapping of the plates. It was thought that one might assume that the diameter was reduced by, say, one inch, that is, by one-half inch all around the outside. This would come inside of all internal projections, thus forming an imaginary cylinder inside of the rivet heads. In this case the assumption is that the water in this outer annular cylinder is stationary, and it is assumed that here there will be a little factor of safety, because, as a matter of fact, even that water will move. Then the water inside this outer stationary envelope is assumed to be flowing in a smooth pipe.

Now, if engineers were impressed with the fact that the loss of head is not on the wetted perimeter, and is not measured by it, but is almost wholly measured by the amount of internal churning there is in the water, they would realize that rivet heads and lapped joints will produce a tremendous effect in churning up the water on the inside of the pipe, as compared to what would exist if it were a perfectly smooth pipe, like glass. The difference in these two cases would be enormous, and the little correction that would

be made by reducing the diameter one inch, would by no means take care of that difference. In every instance, where the subject comes up, engineers should talk about the internal work of the water, both in pure and applied hydraulics, and keep their minds centered on the fact that the loss of head is used up in that way. It is not a matter of perimeter at all, it is not a matter of inward fluid friction with parallel flow at all, it is a matter of the churning up of water, in common phrase. Any cause that will increase this churning action is a further cause of loss of head and must be looked out for. If we would keep our minds pointed in that direction, although it is impossible to evaluate such a cause and to write equations for it, it will prevent our making as bad mistakes as some of us have been guilty of.

The Chair—Probably Mr. Seddon has something that he would like to tell us about this matter.

Mr. J. A. Seddon: I would rather hear from gentlemen of the Club in regard to this. I feel a little away from my bearings.

The Chair—We expect to make you at home here very soon now.

Mr. Seddon: These discharge observations are an extremely interesting series. I knew before that they had been planned by one of the best discharge men in the country, and I realized as soon as I read the paper how carefully and conscientiously the plans have been carried out.

I do not know that I would entirely agree with the gentleman who has worked out the final discharge curve in rejecting any of them. In comparison with quite a large number of such observations on other rivers, I think they are altogether one of the best and most consistent series of discharges that I have ever seen, rejected observations, and all taken together.

When I say consistent, I mean consistent with themselves. I do not know that I am quite so ready to say they actually measure the discharge of the Niagara River. I would like to ask before going on in this line, if Mr. Stewart can tell me the values of the discharges, say at mean lake level, given by the observations of Mr. Quintus in 1893. I did not have the data before me when I got the paper, and it is hard to remember these things.

Mr. Stewart: 230,000 cubic ft. per second.

Mr. Seddon: That is very consistent, very much closer than I thought they were. I had in mind only Mr. Henry's values, earlier and I suppose much cruder observations, and I thought there was a larger discrepancy than there is. Mr. Quintus made his observations with meters. Do you know where they were made, Mr. Stewart?

Mr. Stewart: Portions of them were made below the bridge, and I think the other portion above the bridge; they were made from a steam launch. The steam launch was held against the current, and there are some doubts thrown on his observations because of

the fact that the propeller would influence the current. These observations for velocity might warrant the inference that his velocities were too large on account of the motion of the propeller wheel.

Mr. Seddon: There is just a point that I will bring out in a few words, and that is, I think it is unfortunate where meter observations are made, that there are not, where it is possible, one or two rod floats, or double float observations, made at the same time.

Of course the double float observation is more or less open to criticism. But where a rod float can be run close to the bottom, as it could in this case, having the rod in sections and joining it in suitable lengths, I think there is very little uncertainty in the observation. Such a rod moving at an average velocity of a certain amount, in a certain depth, means just so many cubic feet of water per second passing there. This repeated at proper intervals across the river leaves very little question in the observation, and such observations are really very easily made.

I think that the meter men fall in love with the refinements of their calculations and do not realize that a rough and ready determination of discharge that will satisfy the engineer and that will answer all cavil can be had with but a few hours' work, and a few dollars' expense. I think it is always well where it is possible in this way to join meter work with one or two of such positive measures.

You gentlemen up here are just beginning in this matter, while down on the lower rivers we have had something like twenty years of it, and we started in with the questions all solved by Humphreys and Abbot, now some forty years back. The first observations were probably rather intended to confirm what had been done than really to discover anything new in the Lower Mississippi, but they were laid out so that the questions would be settled for all time, and laid out on a grand scale.

The question is a very important one down there. On it rests the protection of some 25,000 square miles of the valley; the alluvial cream of a continent, back of the levee line and below it. On the levee system the states have spent some $40,000,000, the government some $15,000,000 or $20,000,000, with $20,000,000 more estimated for its completion. With such a work in hand the engineers could lay out these investigations on a large scale and they did so.

The first series on the Lower Mississippi cost, I think, some $80,000, and far from settling the question of discharge, they opened it wide, and it has been wide open ever since. Each new $80,000 series that has been taken there has just turned some good engineer's hair gray trying to explain the contradictions in them. It is from that field and through that experience that we come back to this question of the precision of meter work.

I think my greatest confidence in meters rests on the fact that such men as Haskell and Hider and Price believe in them. I think I value the personal experience of such men rather more than I do any row of figures. But I believe river engineers at large recognize

that the meter is the reliable measure down there, mainly from the fact that it does not in general greatly differ from rod and float observations, and as it is much more simple and rapid to work with, it has come very generally to be used in Lower Mississippi discharges.

Given, a river, say, a mile and a half wide, running eight feet a second, a current that you cannot stem in anything but a steamboat, and it is a pretty convenient thing to have something that you can stick down in it and simply count the ticks on an electric register. But it is principally by the fact that it has been checked a number of times, with double floats and rod floats, and everything possible, that the meter observation is trusted. For all that, it has left some startling records. Take, for instance, a case that perhaps is the most striking. In 1891 the discharge was measured carefully with meters, at Arkansas City and Wilson Point, about ninety miles below, and there was some 200,000 cubic feet per second difference between them. This is nearly the discharge of Niagara, and to pour that excess in to the ninety miles of river would raise its surface some three feet a day, while as a fact it was practically at a stand there. This simply meant an error, on a large scale, in the observations, and as the meters were old and bearings somewhat worn, that was considered sufficient to account for it. But new meters were obtained and the same thing tried the next year, with even greater discrepancies. Meters and observers were changed from upper to lower stations without helping matters, and the result stands as a record of a ten or twelve per cent. error in as careful meter work as, perhaps, has ever been taken.

That, however, is not all of it. There are reasons to think that the error actually lay in too small observations at Wilson Point. Now, all the theory of meters and all the principles of Mr. Haskell's direction meter, is the very simple and obvious conclusion that when a meter measures a current at an angle to the section, it measures a velocity too large for the true one—which should be the normal to it, and every theorist assumes immediately that the meter is an instrument that can easily measure too large a discharge, but I have not yet heard it satisfactorily explained how the meter is able to measure one 12 per cent. too small.

The fact is, the movement of water is not so simple as our text books would assume it to be. I am glad to hear Professor Johnson taking this up, for it is in his line. And the professors are the men to correct it. But, as I hold it in mind, there is no such thing as a continuous linear motion of water in rivers. Every actual slope line there is a line of uniform acceleration that runs into a whirl, and that is the end of it. With the known viscosity of water, there is no other way in which a resistance can be developed that will balance the motion, and it does that in the flow simply by holding it between oscillating extremes, like the balance wheel of a watch or a regulating pendulum. In the flow, then, practically all the energy of the

discharge and fall simply passes into vortex motions, just as it does in the drop over Niagara, only in the river this action is in general distributed and intermittent.

Now, when a meter is put down into such motions, it not only has to face the general drift in the direction of flow which forms the discharge velocities, but it has also a continuous stream of whirls and eddies thrashing through it. That is just what its irregular running shows, the sharp accelerations and checks and stops of cross and reverse currents cutting through it. Applying this to the case in hand, I should say that a bridge site, if the meter is held actually within the line of the piers, is probably the best place possible for such an observation, but if the meter swings down into the marked eddy area just below the piers, I do not think any one can count on its record, and certainly not with the ordinary method of rating it.

I do not believe that this question of rating a meter with something like the irregular motions that it is actually called on to register, has been fully tested. Some marked differences have been recorded from the jerks given to a meter in rowing a boat, while trying to rate it in that way; but the general method is to rate it with a series of uniform motions, as Mr. Stewart does. I think that the men drawing the meter in his ratings would more readily have approached the actual system of velocities that it had to measure, if they had alternated in running and walking and jerking it along. Only, in that case, though I recognize that Mr. Stewart is a brave man by the amount of work he has put into this matter, I hardly think he would have had the courage to adjust that series of observations by the method of least squares.

Mr. Stewart: In the rating of the meters, the method Mr. Seddon suggests was tested in a number of cases. The meter was drawn at speeds varying from 1 to 8 feet per second, and accelerated and retarded several times, in the length of the base. The results seemed to show in all cases that if the rating equation of the meter was that of a straight line, exactly the same results would be obtained as by rating with uniform speeds.

Mr. Cooley: Just for information, I want to ask Mr. Stewart what estimate was made, if any, in regard to the flow at Black Rock Mills, and the use made by the Erie Canal and Welland Canal, that would add to the amount measured in the river proper.

Mr. Stewart: No correction to the discharge has been made on account of the flow through the Erie Canal. No measurement of this was made, but taking an approximate cross-section as 80 feet by 7 feet, a mean velocity of about 2 feet per second would give a discharge of about 1,000 cubic feet per second.

Mr. Cooley: 1,000 feet per second is what they actually pass at Lockport; but there is a very large flow used at times by the mills on the Black Rock Harbor, several thousand feet.

Mr. Stewart: I do not think the mills were using much water at the time of these measurements.

Mr. Noble: Some criticism has been offered by different people in regard to the site at which these observations were made. They were made in a rapid portion of the river where the stream was obstructed and made irregular by the piers of a bridge. During the last few months a series of gaugings has been made at a point about a thousand feet below the bridge, and when the results are available, which will be the course of a few months, it will be possible to check the error from that source, if any. Mr. Stewart is more familiar with this work than I am. He was present during the whole time the gaugings were being made, and reduced nearly all the work in the office, and there is really nothing that I can add in that respect to what he has said.

Mr. Stewart: I would like to call attention to the transverse profile of water surface. In the present case the measurements show the elevation of water surface as about 0.2 feet lower in the middle of the river than on the sides. This does not agree with such records as I can find. Mr. Baumgarten in Annales des Ponts et Chausses, 1848, from measurements on the Garonne River, 500 feet wide, gives the following results: "River rising at rate of 5 feet in 24 hours, velocity equal to 7 feet per second, middle was 0.4 feet above that on the right bank and 0.1 feet above that on the left bank; river falling at rate of 8 feet in 24 hours, velocity equal to 7.5 feet per second, water surface was sensibly a plane, the right bank being about 0.1 foot higher than the left bank." Velocities at the banks were not given. I would like to ask if anybody has seen any records of like measurements.

WRITTEN DISCUSSIONS.

Read February 7th, 1900.

Mr. E. E. Haskell—I feel greatly indebted to Mr. Stewart for a very clear and accurate account of the methods and results of the gauging of the Niagara at Buffalo for the Board of Engineers on Deep Waterways. I feel sure that every engineer interested in the measurements of the flow of water in open channels, especially large rivers, will welcome his paper.

Mr. Stewart has spoken of the continuation of this work by the U. S. Lake Survey, under Colonel Lydecker, and it may be of interest to add that the Lake Survey continued the measurements from the International Bridge until August 1, 1899. Since August 1 and up to the first of the present year the survey has been making measurements at an open section of the river located about 1,800 feet below the bridge. In the continuation of the work at the bridge much attention was paid to observations for better determining the form of the vertical and transverse curves as well as to the measurement of discharges. When the results of this work are added to what Mr. Stewart has presented, I think the whole will be a fair example of what may be done in measuring the discharge of a river with current meters.

The measurements from the open section below the bridge have been prosecuted along substantially the same lines as the bridge work, great care having been taken in determining the co-efficients from the vertical and transverse curves. Nearly a hundred discharges have been measured on this section, and the work here must certainly prove an excellent check upon the results obtained at the bridge.

In regard to methods, I wish to say that they have been, from the inception of the work under the Board, to take nothing for granted.

In regard to the bridge section, it is a much better one for discharge work than many would suppose. As Mr. Stewart has shown in his paper, the current sets very squarely through the bridge in all spans. Aside from the small eddies along the sides of the piers and those caused by the sunken caisson, there were few of any magnitude to be seen. The ease and rapidity and the small expense with which observations can be made from such a bridge are a large consideration. The meter can always be run at the same point for a station, and in general the time required for measuring a full discharge is very much less than in work from boats.

Mr. Stewart has discussed the question of the rating of the meters very thoroughly, but I wish to add a few words. In making the rating of a meter, it was connected up with the cable with which it was used, in exactly the same manner as when used in measuring currents. This is important. A meter when rated should always be run as nearly as possible under the same conditions as those in which it is used. Mr. Shenehon, Resident Engineer in charge of the Lake Survey work at Buffalo, has conducted some most interesting experiments upon the matter of rating meters in running water. He has taken a meter that was thoroughly rated on a still water base to the bridge and there rated a second meter by comparison, in the currents of different velocities, with most satisfactory results. In regard to the accuracy with which the current can be measured with a well rated current meter, I wish to say that I have tested them repeatedly with suitable floats and found them perfectly reliable. Mr. Shenehon has also obtained, in measuring vertical and transverse curves and discharges, some very interesting results with what we call our "two meter" method. To explain this briefly: In measuring a discharge, a vertical or transverse curve, a second meter is placed at some point on one of the curves which we call an index point; this meter is kept at this point and run simultaneously with the first meter, while it is measuring the velocity at the different points on the curves. By this method it will be seen that a ratio is obtained whereby changes in velocity due to changes in stage of water can be corrected.

The Lake Survey has had in operation at Port Huron, in the gauging of the St. Clair river under Mr. L. C. Sabin, Resident Engineer, what we call a multiple meter set, a few words upon which may prove of interest. This set consists of 11 meters and the necessary outfit for suspending them one above another. It is used for

measuring the form of the vertical curves. The interval between the meters is adjustable to suit the depth of water. In use the meters are distributed at each 10th of the depth substantially as explained by Mr. Stewart on page 462. They are then all run simultaneously, and the complete curve determined in the time required to take a single observation. The results so far obtained with this mutiple set are very satisfactory. The next annual report of the Survey will give these results, as also a full account of this recent gauging work.

I think the plate of vertical curves, Fig. 5, of Mr. Stewart's paper will be found very interesting. Quite a variety of forms are shown. In general the form depends upon the depth of water, the smoothness of the bed of the channel, and the slope of the stream where the curve is measured. A set of curves measured on a section located, say, a few hundred feet above the bridge section, at stations directly above the ones here used, would probably be very different in form; and a set measured on a section still further up would present other forms. It is by no means certain that a vertical curve measured on either of the new sections directly above, say, station 4—6-12, would be similar to the one shown. From these curves I wish to point out the difficulty of obtaining the mean velocity by rod floats. Take for example, the curve observed at station 6—10-12; a rod float run at this point would certainly give a velocity greater than the mean. The same is true of many of the other curves shown. There is no possibility of making any corrections. Again, a rod float must reach to within two feet of the bed of the stream at all points if it is to represent actual conditions. There are very few stretches that can be found in our large rivers where the channel is uniform enough in depth and width so that floats can fulfill this condition. In the case of rod floats for the bridge section, at least 18 different lengths would have been required if we were to run one at every meter station.

But by these remarks I do not wish to be considered as condemning the use of rod floats. In the gauging of artificial channels of uniform depth and width, or in rivers of the same, excellent work can be done with them. In the stream of non-uniform flow I do not think they can compare with the current meter, when the latter is in the hands of a careful and painstaking observer.

Mr. Stewart has opened up an interesting topic on page 477 on the use of certain hydraulic formulas, that I would like to discuss, but want of time forbids.

Mr. H. P. Boardman: I have been very much interested in the paper and in the results of the gaugings it describes. But after the careful and exhaustive manner in which most of the field work and computations were carried out, I have been surprised that more space was not devoted to describing the soundings to determine the area of the discharge section.

It is stated that a 41-pound cast iron weight attached to the sounding line was used in the swift and deeper water and a 25-pound weight in the shallower water. The paper does not seem to state

so, but I understand from the author that no correction in depth was made on account of the effect of the current in forcing the sounding line out of plumb. The very careful measurement of the effect of the current on the meter and its cable shows that it was considerable. Why was the similar effect on the sounding weight and its line apparently neglected—or did I misunderstand the author? Though the sounding line and weight may not have offered as much resistance to the current as did the meter outfit, it seems to me that it might be well worth noticing.

I have in mind some soundings recently taken in the Missouri River by line and weight that indicated bottom at an elevation several feet below that at which rock was found by sounding with a pipe jetted down. The soundings by jetting a pipe down were afterwards almost exactly verified by sinking a caisson to and into the rock.

In the Niagara River discharge section, suppose that the soundings taken by line and weight, which always indicate too great depth, would average one foot in excess of actual depths. The discharge section at elevation 567.0 is given as 39,629 square feet and total water width as 1676.6 feet, giving about 23.6 feet average depth. If the correct average depth is one foot less, or 22.6 feet, the error is 4.4 per cent. If the area used is 4 per cent. too great, will not the computed discharge be too great by the same percentage?

I do not know that the soundings would average 4 per cent. too great, but it seems to me they might even exceed that in error.

Mr. Stewart—In reply to Mr. Boardman's question, I would state that in all cases the soundings were taken by casting the lead or weight well up-stream, allowing it to reach bottom, then keeping the line taut until the weight passed the sounding section. The sounding weight was made sufficiently heavy, that the tension on the line would take out all the slack and reduce the curve of the sounding line to the smallest amount. It was thought that the excess of length of line over depth would not exceed about one-half foot under extreme conditions, and that the irregularities of the bottom from boulders would about balance this excess. To correct the areas of cross-section without more direct evidence seemed only to add to the uncertainty. Even allowing a correction of one-half foot to the soundings, but limiting it to the width of river where this uncertainty existed, namely, in spans 3, 4, 5 and 6, for the stage 567.0 we would have a correction to the area of cross-section of but 1.1 per cent and to the discharge of approximately the same per cent. The curve of the sounding line under water evidently cannot be compared with that of the meter cable where the meter is held in position.

ORAL DISCUSSION.

Mr. J. H. Warder here explained the instrument presented to the society for their inspection, intended to measure the rate of speed of moving water.

A Member—I would like to know how you determine the friction. How is that compensated for? The friction may be variable at one time or another.

Mr. Warder—This special metre has been rated by Mr. Haskell as near as can be, and there are so many revolutions indicated and that indicates the velocity of the current.

Mr. Bley—Would not a very little dirt in the water make a difference in the effect upon the metre?

Mr. Warder—Yes, there would be an effect from that. The only thing is to keep everything as clear and clean as possible.

A Member—Would not the friction be greater the swifter the current?

Mr. Warder—I don't know how that might be, it would depend upon circumstances.

Mr. Bley—Have they ever been built with ball bearings?

Mr. Warder—This has no ball bearing.

Mr. Bley—That might relieve it of some friction.

Mr. Artingstall—At some time, as we understand, a liquid, that is, the water, will be filled with all kinds of dirt and filth and rags and things of that kind; will that interfere with the operation of this metre?

Mr. Warder—That might be. That would have to be observed. We have to try it. It has been tried at Bridgeport.

Mr. Artingstall—We know that is not very clean water.

Mr. Warder—We cannot determine those velocities with mathematical accuracy. You cannot use the rod floats in making such tests.

Mr. Boardman—The effect of friction is included in the rating of a meter, and if it is used in water as clear as that in which it was rated, the conditions being practically the same, the results should be satisfactory. I have used a meter in measuring the discharge of artesian wells and the discharge corresponding to a given number of revolutions of the wheel does not vary directly with the rate of revolution. That is, the curve of discharge is not a straight line, showing that frictional resistances, etc., retard the revolution more at certain velocities than at others. If there were no friction, I think the relation would be constant, giving a straight line for the discharge curve.

A Member—Mr. Warder, have you ever rated a meter or seen it rated?

Mr. Warder—I cannot say that I have. They are rated in still water sometimes. This one was rated in still water, as I understand from Mr. Haskell. The rating is taken from some thirty-two different observations and at different rates of speed, and everything done to determine the rating of the meter. The rating of meters, I believe, depends entirely upon the movement of the meter through the water. If we could obtain a body of water moving

at a known and constant velocity in which to rate the meter it would be much more satisfactory.

Mr. Boardman—That is the way a meter is actually rated in an artesian well; that is, we place the meter in the pipe under similar conditions to those under which it will actually be used. We measure the discharge over a weir, recording the rates of revolution of the meter corresponding to the different depth over the weir. This is continued for different rates covering as wide a range as will be covered in use.

Mr. Bley—I would like to ask Mr. Boardman how large a stream was used, because streams have different velocities at different points or sections. The result would be different upon the meter according to where it was placed in the stream.

Mr. Boardman—The rating was in well pipes 6 inches and 8 inches in diameter. The basket that held the meter was just small enough to get into the well easily and hold the meter in the center or axis of the pipe, a fixed position.

Mr. Bley—That would get at it in one way, but probably a different rating would be made if the same meter were taken into a large stream afterwards.

ROSWELL B. MASON, (deceased), the originator and first President of the Society and a group of Pioneer Members who are living, and whose names are still on the membership list of the Society.

ABSTRACT OF MINUTES OF THE SOCIETY.

THE ANNUAL MEETING, 2nd of JANUARY, 1900.

The Annual Meeting of the Society was held at the Grand Pacific Hotel, Chicago, Tuesday evening, January 2, 1900. The meeting was called to order in the parlors of the Hotel by the president, Onward Bates.

The following announcement of the result of the election of officers for the ensuing year was read by the Secretary, and received with applause from the members:

REPORT OF THE TELLERS.

To the Western Society of Engineers:

Chicago, Ill., January 2, 1900.

We the undersigned judges of election have canvassed the ballots for officers of the society for the year 1900 and have the honor to report as follows:

Total number ballots received	151
Total number ballots rejected	4
Total number ballots accepted	147
For President Ambrose V. Powell received	147 votes
For First Vice-Pres. E. J. Blake received	147 votes
For Second Vice-Pres. William H. Finley received	147 votes
Foı Treasurer Ralph Modjeski received	147 votes
For Trustee Bion J. Arnold received	147 votes

Yours respectfully,

B. F. GRANT.
H. E. WILLIAMS.

The members then repaired to the Banquet Hall and the following reports to the Board of Direction were read in the intervals between courses:

REPORT OF THE TREASURER.

Chicago, December 30, 1899.

Gentlemen:

I respectfully submit herewith a statement of the treasurer's account for the year 1899, as follows:

NET RECEIPTS.

Cash balance received from 1898	$1,543.92
Advertising	1,481.30
Entrance fees	524.00
Journal subscriptions	333.25
Total dues	3,909.50
Rent	230.89
Sundries, sale Journals, re-prints, etc	520.83
Total	$8,543.69

NET EXPENDITURES.

Journal	$1,682.98
Services	2,197.21
General printing	377.61
Stationery and postage	269.64
Library	393.79
House expense	865.39
Sundries	110.75
Commission, account advertising	201.61
One certificate of deposit maturing March 2d, 1900	500.00
One certificate of deposit maturing April 11th, 1900	500.00
One certificate of deposit maturing June 12th, 1900	500.00
One certificate of deposit maturing Sept. 1st, 1900	500.00
Cash balance in bank	444.71
Total	$8,543.69

Respectfully submitted,

CHAS. W. MELCHER, Treasurer.

COMMITTEE ON FINANCE.

NELSON O. WHITNEY, Chairman.

Mr. Whitney, chairman of the committee, being absent by reason of sickness, Mr. Powell of the committee read the following report:

REPORT OF THE FINANCE COMMITTEE.

Chicago, Ill., January 2, 1900.

Gentlemen:

Your committee beg leave to submit the following report on the financial condition of the Western Society of Engineers for the year of 1899:

BALANCE SHEET.

RESOURCES.			LIABILITIES.	
Cash on hand December 31, 1889		$2,494.71	Bills payable	$ 155.56
Dues for 1899, unpaid		307.50	Estimated journal expenses	752.00
Bills receivable		99.35	Profit and Loss	4,354.17
Journal Advertising 1898	$ 189.00			
" " " 1899	1,413.67			
" Subscription 1898	79.00			
" " " 1899	78.50			
Journals	600.00			
		2,360.17		
Total		$5,261.73	Total	$5,261.73

Detailed Statement of Receipts and Expenditures for 1899 (follows).

Of the cash in the hands of the Treasurer $2,000 is in the form of interest bearing certificates drawing three per cent.

Respectfully submitted,

N. O. WHITNEY.
AMBROSE V. POWELL.
CHAS. W. MELCHER.
Finance Committee.

RECEIPTS—1899.

MONTHS 1899.	Past Dues.	1899 Dues.	Past Sub.	1899 Sub.	Past Advt.	1898 Advt.	1899 Advt.	Entr'ce Fee.	Rent.	Sales Journal.	Sundries.	1900 Sub.	1900 Dues.	TOTAL.
January..........	$ 50.00	$1,277.50	$15.00	$115.50	$	$241.90	$	$ 80.00	$ 60.00	$ 48.65	$ .25	$	$	$1,889.30
February	20.00	407 50	6.00	29.50		105.00		60.00	26.70	19.65	.50		7.50	681.85
March	60.00	272.50		37.75		86.00		35.00	26.70	95.60	19.90			633.45
April............	30.00	364.50	2.00	41.50		35.00		25.00	7.50	45.60		2.00	3.00	556.10
May		216.50	2.00	16.00	43.50	23.00		36.00	28.50	13.35	19.80			398.65
June.............	7.50	224.00		8.00		79.00	30.00	98.00	8.15	3.66	7.50			465.81
July.............		237.25		8.00		86.00	197.00	60.00		2.00	8.10			598.35
August...........		171.75		22.00		23.00	111.00	32.00	7.50	50.11	30.11			447.47
September		90.50		2.00	12.00	24.00	72.00	20.00	30.00	13 30	41.40			305.20
October..........		175.50		2.00			27.00	23.00	15.00	12.30	1.51			256.31
November.........		180.00		12.00		83.50	78.00	44.00	13.34	5.10				415.94
December.........		115.00		6.00		30.00	149.50	10.00	20.84	5.60	8.40	6.00		351.34
	$167.50	$3,732.50	$25.00	$300.25	$55.50	$816.40	$664.50	$523.00	$244.23	$314.92	$137.47	$8.00	$10.50	6,999.77

Cash in hands of Treasurer December 31, 1898.... $1,543.92 }
Petty cash in Secretary's hands December 31, 1898 50.00 } Total Cash on hand.......... 1,593.92

$8,593.69

EXPENDITURES—1899.

MONTHS 1899	Journal 1898.	Journal 1899.	Services.	General Printing.	Stat. and Postage.	House Expense.	Library.	Sundries.	Journal Com'ns.	Furn. and Fixtures.	TOTAL.
January...........	$ 85.06	$ 30.60	$ 267.35	$ 34.65	$ 50.51	$ 67.25	$ 9.90	$ 16.54	$ 22.25	$	$ 584.11
February..........	5.15	44.20	97.10	4.65	20.63	74.22			16.12		262.07
March.............	289.81	97.03	192.12	40.45	26.75	73.50	3.90		21.75		745.31
April.............	19.50	426.55	254.60	13.35	21.22	66.37	.75				802.34
May...............		53.82	173.88	10.36	29.36	67.00	91.58	6.00	24.25		456.25
June..............		226.88	188.80	19.85	21.94	74.27	31.25	5.20			568.19
July..............		1.50	171.25	4.80	27.29	64.61	26.65	3.75	15.75		315.60
August............		152.20	169.51	132.90	24.68	70.45	7.35				557.09
September		16.90	172.20	13.20	15.51	61.75	8.56	44.65			332.77
October...........		41.20	160.90	12.40	24.25	99.65	67.02		65.62		471.04
November..........		14.30	175.65	13.80	19.93	63.90	45.75	22.61		7.25	363.19
December..........		178.28	173.85	38.10	41.70	72.99	78.80	12.00	35.87	9.43	641.02
	$399.52	$1,283.46	$2,197.21	$338.51	$323.77	$855.96	$371.51	$110.75	$201.61	$16.68	6,098.98

Cash in Treasurer's hands December 31, 1899........$2,444.71 }
Petty cash in Secretary's hands December 31, 1899.. 50.00 } Total Cash on hand.......... 2,494.71

$8,593.69

REPORT OF THE AUDITING COMMITTEE.

Gentlemen:

The Auditing Committee desires to report that it has carefully examined the society's accounts for the year 1899 and finds that they have been accurately and excellently kept by both the Secretary and the Treasurer. All moneys received as per the Secretary's record have been turned over to the Treasurer and the expenditures are all duly authorized by the Board of Direction. The balance on hand is $2,494.71, which we find to be invested or deposited as stated by the Secretary and Treasurer.

Respectfully,

E. GERBER.
G. A. M. LILJENCRANTZ.
R. M. SHANKLAND.
Auditing Committee.

REPORT OF THE SECRETARY.

Chicago, December 31, 1899.

Gentlemen:

I have the honor to submit the following report for the year 1899:

TABLE OF MEMBERSHIP CHANGES.

	Jan. 1, 1899.			Jan. 1, 1900.			Losses.				Addition.	
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	Transfers.	Resignations.	Dropped.	Deaths.	Transfers.	Election.
Hon. Members...	1		1	1		1						
Active Members .	274	119	393	265	146	411		5	12	4		41
Junior Members..	7	3	10	25	18	43				1		33
Assoc'te Members	25	3	28	28	1	29			3	1		4
	307	125	432	319	165	484		5	15	6		78

A net gain in membership for the year of 52.

The following are the names of deceased members:
Active member, M. C. Bullock, died January 12, 1899.
Active member, R. J. McClure, died March 17, 1899.
Active member, Chas. M. Higginson, died May 6, 1899.
Active member, Ferdinand Hall, died November 22, 1899.
Junior member, Norwood DeHart, died May 11, 1899.
Associate member, Peter W. Neu, died February 4, 1899.

During the year nineteen meetings have been held in our hall, and one, a lecture by Professor E. E. Barnard on "What Photography has done for Astronomy," to which ladies were invited, in Steinway Hall.

The following is a list of papers read and discussions had at these meetings:

Tuesday evening, Jan. 3, 1899.
Annual meeting.

Wednesday evening, February 1, 1899.
"Establishing Street Grades," by Chas. P. Chase.

Wednesday evening, February 15, 1899.
"Tables of Excessive Precipitations of Rain at Chicago from 1889 to 1897, Inclusive," by Edwin Duryea, Jr.

Wednesday evening, March 1, 1899.
"Electrical Radiation With Its Application to Signaling Through Space," by Arthur V. Abbott.
Wednesday evening, March 15, 1899.
"The Development of a Central Lighting Station," by Louis A. Ferguson.
Wednesday evening, April 5, 1899.
"Effect of Different Speed and Radii of Curves Upon the Inclination of Bicycle Tracks," by John C. Quade.
Wednesday, April 5, 1899.
"Some Hints on Bridge Designing," by Oscar Sanne.
Wednesday evening, April 19, 1899 (Ladies' evening).
"Among the Castles and Abbeys of Great Britain," by W. J. Karner. Ladies present and refreshments were served.
Wednesday evening, May 3, 1899.
"A Railway Pile Driver," by G. W. Smith.
Wednesday evening, May 3, 1899.
"Some Notes on Concrete in Freezing Weather," by W. A. Rogers.
Wednesday evening, May 17, 1899.
"Steel vs. Wood Tanks," by T. W. Snow.
Wednesday evening, June 7, 1899.
"City Subways," by W. T. Casgrain.
Wednesday evening, June 21, 1899.
"The Salient Features of the Chief Engineer's Annual Report of the Drainage Canal of the Sanitary District of Chicago, for 1898," by Isham Randolph.
Wednesday evening, August 2, 1899.
"A Boulevard Connection Between the North and South Sides of the City of Chicago," by L. L. Stimpson.
Wednesday evening, October 4, 1899.
"What Photography Has Done for Astronomy," by Professor E. E. Barnard.
Wednesday evening, November 1, 1899.
"Civil Construction, with Brief Methods of Estimating Cost," by G. A. M. Liljencrantz.
Wednesday evening, November 15, 1899.
"Cement Coating, a New Method of Waterproofing Brick Walls and Masonry," by C. E. Schauffler.
Wednesday evening, December 6, 1899.
"Electrical Underground Construction," by G. B. Springer.
"Dock Construction," by Victor Windett.
Wednesday evening, December 20, 1899.
"Discharge Measurement of the Niagara River at Buffalo, N. Y.," by Clinton B. Stewart.
"175 Foot Counter-Balanced Swing Bridge Over the North Branch of the Chicago River," by Albert Reichmann and Walter A. Rogers.

All the papers were liberally illustrated with stereopticon views.

Yours truly,

Nelson L. Litten, Secretary.

REPORT OF THE LIBRARIAN.

December 31, 1899.

Gentlemen:

I have the honor to submit the following report concerning the library of the society.

During the year the following additions to the library have been received:

Bound books by purchase	43
Bound books by exchange	31
Bound books as gifts	372
Pamphlets	277

Miscellaneous periodicals as gifts	247
Unbound volumes, periodicals as gifts	64
Catalogues	4
New exchanges	3

During the year 261 books have been bound.

Total number of books accessioned to Dec. 31, '99	3,384
Total number of books accessioned to Dec. 31, '98	2,828
Increase in number of books accessioned for the year	556

In the beginning of the year we lacked the very rare Vol. No. 1, 1837 to 1841, to complete our set of the "Minutes of the Proceedings of the Institution of Civil Engineers" (London). After a year of fruitless search for it the Institution was induced, through the influence of our esteemed member. Mr. Elmer L. Corthell, to favor us with a copy. The Western Society of Engineers' library is one among a few libraries in this country possessing a complete set to date of this Institution's transactions and proceedings dating back to 1836.

The following is a partial list of valuable sets of books on the library shelves.

Complete set to date of Reports of the Chief of Engineers, U. S. A.

Complete set to date of Transactions and Proceedings Institution of Civil Engineers—(London.)

Complete set to date of Transactions American Society of Civil Engineers.

Complete set to date of Transactions American Society of Mechanical Engineers.

Complete set to date of Transactions Institute of Mining Engineers.

Complete set to date of Journal of the Association of Engineering Societies.

Complete set to date of Transactions Engineers' Club of Philadelphia.

Complete set to date of the Annual Reports of Chicago Board of Trade.

Complete set to date of the Board and Department of Public Works, Chicago (except 3 vols.).

Complete set to date of the Board of the Sanitary District of Chicago.

Transactions Institute of Mechanical Engineers—London.

Transactions Liverpool Engineering Society—Liverpool.

Reports of the American Railway Master Mechanics' Association.

Master Car Builders' Reports.

Engineering, of London.

Engineer, of London.

Engineering News.

Engineering Record.

Engineering and Mining Journal.

Engineering Magazine.

Cassier's Magazine.

Encyclopaedia Britannica, with American additions to date—30 volumes.

The Century Dictionary—10 volumes.

Annual Reports U. S. Geological Survey to date.

Topographic maps U. S. Geological Survey. The Government has selected this library as a permanent depository to receive all these maps as issued.

The large number of pamphlets which have been accumulating for many years past, have been provided with a case, classified and properly indexed.

THE READING ROOM.

There are received in the reading room regularly in exchange for the Journal of the society 44 foreign publications, 140 Canada and domestic.

The thanks of the society are due to Mr. Frank P. Kellogg, one of our members, for a vast deal of time and labor bestowed without charge, caring for and exchanging duplicate periodicals. During the year 1899 he has secured for the library by the exchange of duplicates 21 volumes.

Yours truly,

NELSON L. LITTEN, Librarian.

COMMITTEE ON LIBRARY.

As this question of library work has been covered in the Librarian's report, very little remains for me to say in addition. The efforts of the Library Committee during the past year have been directed more particularly toward bringing up the physical condition of the library. For years past each Committee on Library has been trying to bring out of a chaotic state what has become a valuable collection of books. That work has been thoroughly done up to the present year and at the close of this year we have called in expert librarians so that as the library now stands we believe it will be strictly up to date. It is classified and indexed on a card system so that books on all subjects and any information desired can be had as readily as possible.

During the past year a great many volumes, as many as five hundred, have been received from one source and another. We have purchased, or will have purchased as soon as delivered, in the neighborhood of sixty volumes, and the main work has been in completing volumes which in the past have been incomplete and consequently not valuable. With these remarks and the Librarian's Report, I believe the subject has been covered.

George P. Nichols, Chairman.

REPORT OF THE PUBLICATION COMMITTEE.

Gentlemen:

We beg to submit the following tables of statistics regarding the finances of the Journal, which tables have been compiled from the records of the Secretary of the Society.

These statistics show clearly the financial success of the Journal. It is not intended that the Journal shall be a means of income to the Society, but it is the desire of all interested in its success that it shall pay for itself and not require an appropriation from the general funds of the organization. The difference between the cash receipts and expenditures for the first three volumes of the Journal is a deficit of only $32.72, against which are "bills receivable amounting to $665.50, a considerable portion of which are collectable accounts.

The financial results of the current year (1899) are even more satisfactory, since the cash receipts and "bills receivable" together exceed the total cost of the Journal by $432.29. The bills for advertising will not become due until after January 1, 1900. If $250 of this sum should remain on the books uncollected, there would still be a balance of $182.29 to the credit of the Journal.

It must not be lost sight of that the Journal brings in several hundred dollars' worth of exchanges each year, thus contributing largely toward making our library what it is. Up to this time the management and editing of the Journal has been done by the members of the Publication Committee. But few of our members realize the responsibility and labor the members of this committee have to assume. During the first two years that we published the Journal the enthusiasm of those who championed the new departure, of publishing our own Journal, made the burden of this work seem light to them. In this connection the society owes a great debt to the unselfish devotion and labor of the members of the Publication Committees of 1896 and 1897. They were Messrs. Reynolds, Johnston and Billin for 1896 and Messrs. Reynolds, Johnston and Keating for 1897. During the past two years these members have not been able to devote the time and labor to the Journal that they formerly gave.

The present members of the Publication Committee have given to the Journal such time and attention as they could take from their business affairs, aided at all times by the Secretary, Mr. Litten. Fortunately for the members of the committee this year, but unfortunately for the society at large, the task has been lightened by a lack of matter to publish.

There are a few changes which, if made in the Journal with the beginning

COMPARATIVE STATEMENT OF THE CREDIT ACCOUNTS OF THE JOURNAL

AT THE CLOSE OF EACH OF THE FOUR YEARS DURING WHICH IT HAS BEEN PUBLISHED.

	DECEMBER 31, 1896. Account of 1896 Journal Vol. I.			DECEMBER 31, 1897. Account of 1897 Journal Vol. II.			DECEMBER 31, 1898. Account of 1898 Journal Vol. III.			DECEMBER 31, 1899. Account of 1899 Journal Vol. IV.		
	Cash Received.	Bills Receivable	Total Earnings.	Cash Received.	Bills Receivable	Total Earnings.	Cash Received.	Bills Receivable	Total Earnings.	Cash Received.	Bills Receivable	Total Earnings.
ADVERTISEMENTS.	$1,181.00	$1,172.00	$2,353.00	$ 848.00	$1,147.92	$1,995.92	$1,028.60	$971.40	$2,000.00	$ 664.50	$1.523.50	$2,188.00
SUBSCRIPTIONS.	351.50	54.00	405.50	342.05	119.00	461.05	305.95	78.00	383.95	300.25	78.50	378.75
SALES.	81.30		81.30	62.40		62.40	118.12	21.00	139.12	23.40		23.40
TOTALS.	1,613.80	1,226.00	2,839.80	1,252.45	1,266.92	2,519.37	1,452.67	1,070.40	2,523.07	988.15	1,602.00	2,590.15

CASH RECEIPTS ON ACCOUNT OF JOURNAL.

RECEIVED DURING	ON ACCOUNS OF JOURNALS OF 1896. (Vol. I.)	1897. (Vol. II.)	1898. (Vol. III.)	1899. (Vol. IV.)	TOTALS.
1896	$1,613.80				$1,613.80
1897	1,028.55	$1,252.45			2,281.00
1898	7.50	1,067.42	$1.452.67		2,527.59
1899	58.30	47.25	1,057.87	$988.15	2,151.57
TOTALS..................	$2,708.15	$2,367.12	$2,510.54	$988.15	$8,573.96

CONDENSED STATEMENT OF JOURNAL ACCOUNTS, DECEMBER 31, 1899.

ACCOUNT OF	Cash Received.	Bills Receivable	Total Earnings.	Total Expenses.	Net Earnings.
1896 Journal (Vol. I.)	$2,708.15	$ 211.50	$ 2,919.65	$2,506.55	$ 413.10
1897 " (" II.)	2,367.12	220.00	2,587.12	2,394.12	193.00
1898 " (" III.)	2,510.54	234.00	2,744.54	2,717.86	26.68
1899 " (" IV.)	988.15	1,602.00*	2,590.15	2,157.86‡	432.29
TOTALS	$8,573.96	$2,267.50	$10,841.46	$9,776.39	$1,065.07
AVERAGES PER YEAR..	$2,143.49		$2,710.36	$2,444.10	$266.27

NOTE—No portion of the Secretary's salary has been charged to the account of the Journal.

* This amount is largely made up of advertising accounts, which do not fall due until after January 1, 1900.

‡ This amount includes $183.12 of unpaid commission on advertising which only becomes due as the accounts are paid in.

of a new year would add much to its value to all the members. The most radical one that is suggested is the issuance of ten numbers per annum instead of six, as at present, these issues to be made on a fixed day of each month, except the months of July and August. If this were done it would obviate the necessity for separate advance publications, and would permit publication of all papers in advance of their presentation to the society.

Another change which is recommended is that the "proceedings" of the society be made a more conspicuous and important feature of the Journal. At present a scant page of "abstracts of proceedings," printed in brevier type in the back of the Journal is all that the non-attending members can turn to to see what is happening in the society in the way of routine and general affairs. The proceedings should be in as brave type as anything published, and they should be where they would be readily seen and read. All notices of importance or interest should be preserved in this way, as often these mark the growth of the organization.

At one time "abstracts from other publications" were quite important features of the Journal. But it took a great deal of time and careful study to keep up this feature in a creditable way, and as no one could be found willing to devote the time and talent gratuitously to the society, the abstracts have disappeared. If properly conducted, this department might be made invaluable to our members.

A department of great usefulness to the members, and one that would tend to bring a great deal of valuable literature to the library, would be a department of "Book Notes," restricted, of course, to technical literature.

And so on. Several important changes and features of improvement to the Journal tending to make it a more useful and a more valuable publication suggest themselves, and with such a publication coming to the members monthly, it would tend to arouse the interest of all, and more members would be found anxious to contribute to its columns than can now be coerced into writing papers for the society.

The society is carrying on a publication that should be of very great value and importance to the engineering world. The work should be well done, and no pains spared to make the Journal second to none of its class.

An organization designated as a Western Society must needs develop, and that, too, at a quick pace, or it does not deserve the name. This society has grown wonderfully the past four years, owing in no small measure to the influence of the Journal, and the time has come for the scope of this publication to be increased correspondingly.

T. L. CONDRON,
Chairman of the Publication Committee.

COMMITTEE ON MEMBERSHIP.

The only thing I would like to add to the Secretary's Report is that besides the fifty-two new members we have seven additional applications. That brings the total membership up to 495. (Applause.) We were striving to reach 500, and it is hoped that with a very little assistance from a few members we will be able to reach that point within a short time.

AUGUST ZIESING, Chairman.

REPORT OF COMMITTEE ON THE PARIS EXPOSITION.

Gentlemen:

The Paris Exposition Committee, which you appointed last March to co-operate with Mr. Willard A. Smith, Director of Civil Engineering and Transportation, to secure an engineering exhibit for the Paris Exposition, desires to report as follows:

Soon after its first meeting in March the committee sent out a circular to all its members, calling their attention, in general terms, to the proposed engineering exhibit and soliciting their co-operation. The following is a copy of the circular:

Western Society of Engineers.

To Members:

The Paris Exposition of 1900 will be, without doubt, one of the greatest, if not the greatest event in the world of science, art, industry and commerce since history began.

The Western Society has been requested by Mr. Willard A. Smith, one of our members, and Director of Transportation and Engineering for the U. S. Commission, to send an exhibit under the auspices of our society, illustrating the engineering practice in the West.

The undersigned committee was appointed by the society Board of Direction for the purpose of securing an interesting exhibit for the section allotted to the Western Society of Engineers.

The committee is able to state so far that the space, as well as the transportation of exhibits, if sent collectively, will be free of charge. The committee has no doubt that with the earnest co-operation of the members of the society, it will be successful in obtaining a very valuable and interesting collection, and one which will not only attract the attention of the engineering profession abroad, but also of all of those of our countrymen who are interested in the progress of engineering science.

The committee expects that you will take an active interest in the success of this work, so that it may reflect credit on our society, and in general on our engineering profession. Small models of engineering works are very desirable; also relief maps, large photographs and large carefully prepared plans of interesting features will be acceptable. As the exhibit will be under the auspices of the Western Society of Engineers, it will not be confined to members only.

The committee will be glad to receive suggestions tending to further the interests of its purpose. Those who contemplate the preparation of models are invited to confer with the committee, as it can put them in communication with model makers and obtain estimates for the work. The time is short; you are requested to act promptly. Address all communications to the Paris Exposition Committee, Western Society of Engineers, 1737 Monadnock Block, Chicago.

RALPH MODJESKI, Chairman.
PROF. N. O. WHITNEY.
ISHAM RANDOLPH.
THOS. T. JOHNSTON.
BION J. ARNOLD.
Paris Exposition Committee.

In May, another circular (marked A) containing more complete and detailed information was sent out to about five hundred different firms, inviting them to exhibit under the auspices of the Western Society of Engineers. The exceptional terms which the U. S. Commission offered to this class of exhibits were stated in this circular. Through these circulars, as well as through personal efforts of Mr. Smith and of the members of the committee, the following gratifying results have been obtained so far, and it is reasonable to hope that these results will still be considerably increased before the opening of the Exposition.

A perspective view of the space allotted to the United States in the Transportation and Civil Engineering Building, which will accommodate part of our exhibit, is hereto attached.

Due to the difficulties in classification and location, it was found impracticable to place the Western Society's exhibit under one general sign. Each

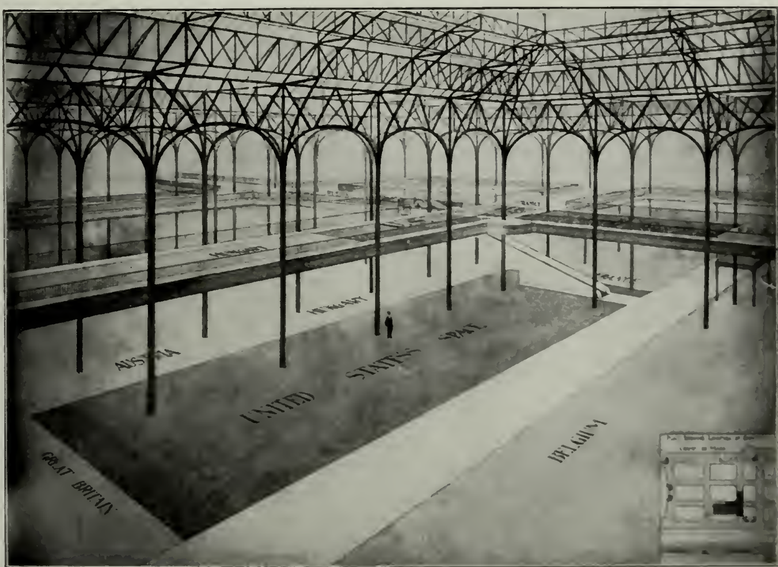


FIG. 1.—View of United States space in the Transportation and Engineering Building.

exhibit, however coming under the auspices of our society, will have a label attached, reading as follows: "Exhibited under the auspices of Western Society of Engineers, Chicago, Ill."

The exhibits secured, so far, as forming the Western Society exhibit, are as follows:

Sanitary District of Chicago, three large models, including one relief map (ready for shipment), one model of controlling works and model of earthwork and rock channel spanned by a swing bridge; also 16 large photographs. These models are beautifully executed and represent a considerable outlay of money on the part of the Sanitary District. They were obtained through the kind offices of a member of the committee, Mr. Isham Randolph, Chief Engineer.

In connection with this exhibit, the Ingersoll-Sargent Drill Company, the Rand Drill Company and the Bucyrus Steam Shovel Company will exhibit models of their machinery, etc.

The Chicago, Milwaukee & St. Paul Railway, through the kind offices of our President, Mr. Bates, will exhibit a model of a Howe truss bridge, which will be of great interest.

The Illinois Central Railroad, through the kind offices of Mr. Wallace and Mr. Parkhurst, will exhibit a model of their standard ballasted timber trestle. This model has already been completed.

The Kansas City & Memphis Railroad Bridge Company, through Mr. Washburne, President, will exhibit a model and photographs of the Memphis Bridge.

The Q. & C. Co., the Sheffield Car Co., the Continuous Rail Joint Co., and the Weber Railway Rail Joint Manufacturing Co. will all have separate exhibits of their rail plates and rail joints.

The Dean-Chamberlain Manufacturing Co. will have models of pneumatic paint machinery.

The J. G. Brill Co., of Philadelphia, will exhibit working models of tramway trucks.

The Chicago Great Western Railway Co., through the kindness of Mr. Samuel C. Stickney, valuable charts, maps, etc., showing operative and construction methods.

The Long Island Railway Co., maps, drawings and photographs.

A member of the committee, Mr. Corydon T. Purdy, is preparing an exhibit illustrating the construction of an American high steel frame building. The list of subjects in this exhibit is given below:

A model of the steel frame work of the building.

A model of the completed building.

Samples of connections of beams to columns in full size.

Samples of connections of beams to beams in full size.

Illustrations of spandrel construction, painted full size on wood, made about 3-16-in. thick, hung or hinged to turn readily about the column.

The general architect's drawings and specifications.

The general iron plans and specifications.

A copy of all shop drawings of iron construction.

One or two models in full size.

Samples of the terra cotta construction, which exhibit is hoped to be made very complete.

Samples of brick and granite.

A separate model of the foundations.

Samples of the soil on which the building is constructed.

An exhibit of the elevator construction.

An exhibit of the steam-heating construction.

An exhibit of the plumbing construction.

An exhibit of the electric work.

Mr. Purdy has been appointed by Mr. Willard A. Smith as Honorary Expert and Architectural Engineer to prepare this exhibit.

Mr. Smith is preparing a collection of unmounted photographs illustrating American engineering work, machinery and processes. A special place in the gallery of the space allotted to the United States will be reserved for this purpose. These photographs will be shown either in albums or mounted on the wall, or in any way which may become most feasible and practicable. The committee wishes to invite all members to furnish such unmounted photographs as they may deem of interest for this collection.

Some hundreds have already been secured and it is desired to have this collection as large, as complete and as interesting as possible. These photographs can be sent to Mr. Willard A. Smith, Director of Civil Engineering and Transportation, U. S. Commission for the Paris Exposition, Auditorium Building, Chicago, and should be accompanied by sufficient information for intelligent labeling. It is expected that these photographs will be furnished as a gift, as it will be impossible to return them. There will be no expense involved to the contributors, except the cost of the photographs themselves.

The committee wishes to add that it is not yet too late to join this exhibit by contributing models, especially if these are on hand or if they can be made in a short time.

To conclude, the committee would recommend that the thanks of the society be extended to Mr. Onward Bates, Mr. J. F. Wallace, and Mr. H. W. Parkhurst for their arduous co-operation with the committee and liberal contributions to this exhibit.

RALPH MODJESKI, Chairman,
PROF. N. O. WHITNEY,
ISHAM RANDOLPH,
T. T. JOHNSTON,
B. J. ARNOLD,
C. T. PURDY,
Paris Exposition Committee.

CIRCULAR A.

Auditorium Building, Chicago, May 15, 1899.

The Paris Exposition of 1900 has devoted one of its principal buildings in the best location in the Champs de Mars, to the subject of "Civil Engineering and Transportation." In this building the Commissioner General for the United States has secured a prominent space adjoining that of other leading nations.

The decision to locate all heavy and large railway exhibits at the Bois de Vincennes, as well as the large and important bicycle, automobile and life-saving exhibits, enabled him to secure large additional space for these classes and thus greatly relieve the pressure for space in the "Palace of Civil Engineering and Transportation."

Germany, Great Britain and France are making elaborate and extensive preparations for their engineering exhibits. We desire to have an exhibit of American Engineering which shall properly represent our country. Every consideration of patriotism, business sagacity and professional pride calls for it. It has met with the cordial approval of the American Society of Civil Engineers and the Western Society of Engineers, both of which organizations have appointed able committees to co-operate with this department of the commission in securing the best possible representation.

Among the special features of interest will be topographical models of the Chicago Drainage Canal, and of the principal American cities. The States of Massachusetts and New York will make especially valuable exhibits of their engineering development.

A COLLECTIVE EXHIBIT.

As most exhibits in this class must be by means of models, photographs, drawings, maps, specimens of materials, and small articles, it is evident that the collective plan can be followed with great advantage. By this means a thoroughly representative exhibit can be secured at a very small expense to each exhibitor.

The plan is as follows: An engineer of ability, speaking French as well as English (and possibly German) will be secured to take charge of the exhibits. When in Paris he will have two or more competent assistants to aid in installing and caring for exhibits, seeing that they are properly entered for award, distributing printed matter, and packing and shipping the exhibits home again.

COST OF EXHIBITING.

We propose to receive the exhibits properly packed for trans-atlantic shipment, at our warehouse in New York, where they are to be delivered at the exhibitor's own expense. From that point we assume entire charge of them, until their final return to the exhibitor again at New York. Transportation, customs entry, storage of packing cases, installation, care of exhibits, explanation by competent attendants, judicious distribution of printed matter—every service and every expense will be covered by the charge which we propose to make of six dollars ($6) per square foot of floor or

wall space. This will provide for the "flooring charge" of the French authorities, platforms, counters, tables, partitions, cases, framing of pictures, etc., in uniform style, protection from the sun, and general decoration of the space.

It is proposed to have the engineer in charge begin his duties by the first of July next. He will undertake to communicate with exhibitors in person, where possible, or by correspondence, giving them the assistance of his advice in the preparation of their exhibits. It will be his duty to study and familiarize himself with the exhibits, so that he may be fully prepared to answer questions and otherwise represent the exhibitor efficiently. He will prepare a uniform style and size for printed matter, so that visitors can secure full sets for binding if desired.

NATURE OF EXHIBITS.

Models of machinery should, as far as possible, be working models which can be operated by means of electric motors. They should be made to scale, and should be accompanied by photographs showing the machines in actual work.

Photographs should be sufficiently large to be clearly seen when hung on the walls, which will be limited to twelve feet in height. Only high grade photographs will be accepted. They should be mounted and furnished with mats (if same are desired) but unframed. The frames, glass, etc., will be provided in Paris—the expense being included in the space charge.

Albums of photographs, blue prints or other designs should be attractively bound and substantial enough to stand considerable handling by visitors.

Drawings, Maps, etc., should be made attractive as well as instructive. They should be shipped flat or in rolls and will be properly mounted in Paris.

Small articles may of course be exhibited in full size—though probably not more than from 150 to 200 square feet can be provided for any one exhibit.

It is evident that an exhibit of this kind will be reasonably efficient and comparatively inexpensive. It is intended to make shipment from New York by December 15, so that there may be abundant time for installing the exhibit complete by the opening of the Exposition. All contracts for platforms, partitions, counters, tables, framing, railing, cases, decoration, etc., will be made beforehand in Paris.

It must be evident that the price named (six dollars per square foot of wall or floor space) is reasonable. The entire sum will be expended to advantage. The trouble and expense to the exhibitor will be reduced to a minimum. The advantages of this arrangement can be extended only to what are considered desirable exhibits. Applications will be passed on as soon as received, subject to enough being finally received and accepted to make the plan an assured success. Space will then be allotted and a payment of one-half of the space charge will be called for—the remainder to be paid when the exhibit is shipped to our New York warehouse.

We solicit a prompt and careful consideration of this subject. The classification of this department is given below. It will be possible to take into this collective plan small articles for marine or railway use not strictly included in the civil engineering classes, but coming within the transportation group.

Bear in mind that outside of the cost of the article exhibited the only expense in addition to the charge of six dollars per square foot, will be freight to New York and return.

All communications and correspondence should be addressed to

Willard A. Smith,

Director of the Department of Civil Engineering and Transportation,
Auditorium Building, Chicago.

Approved:

Ferdinand W. Peck,

Commissioner-General.

MATERIALS, EQUIPMENT AND PROCESS RELATING TO CIVIL ENGINEERING.

Building materials (other than timber, materials extracted from quarries, metals and ceramic products): lime, cement, plaster, artificial stone, etc. Equipment and methods of production of these materials.

Methods of testing building materials.

Preparation of building materials: implements and methods used by stone cutters, masons, carpenters, slaters, joiners, locksmiths, plumbers, glaziers, painters, etc.

Equipment for and methods used in earthwork: hand tools, excavations, scrapers, barrows, dump-carts, service tracks, hand-carts, trucks, etc.

Equipment for and methods (other than pumps) for preparing foundations: piles, pile drivers, screw piles, pneumatic apparatus, etc.

Equipment for and methods of transporting and distributing material.

Equipment for and methods for the maintenance of roads, streets, public promenades, etc.

Equipment for lighting seacoasts and beacons.

Equipment for and methods used in distributing water and gas (not including gas meters).

Equipment for and methods used in pneumatic telegraphy.

MODELS, PLANS AND DESIGNS FOR PUBLIC WORKS.

Roads and other public highways on land. Bridges and viaducts.

Inland navigation: improvement of rivers; construction of canals; dams, locks, lifts, fixed bridges, or draw-bridges, canal bridges, reservoirs and feeders, pumping stations, mechanical towing and warping; equipment used for the development of river ports.

Sea ports; general arrangement: jetties, basins, locks, swing bridges; equipment for development (not including shipping).

Maritime canals.

Provision of lights and beacons for seacoasts.

Protection against flooding by rivers or by sea.

Railways, as regards plan and profile of the line, and engineering works.

Construction and maintenance of streets in cities.

Water supply, sanitation and gas lighting of cities.

System of telegraphy by compressed air.

Statistics, maps and publications relative to public works.

Construction of the International Exposition of 1900.

The collective plan as outlined above, will also apply to all models, photographs, drawings, etc., and small articles included in the following:

EQUIPMENT FOR RAILWAYS AND STREET RAILWAYS.

1. Railways of standard or narrow gauge.

Permanent way: grading, ballast, etc., ties, rails, chairs, fish-plates and other parts of the track; switches and crossings; stations; transfer tables, turn tables and bridges; weighing apparatus, gauges and accessories; fixed signals, systems and apparatus for securing the safety of traffic; water supply; snow sheds and fences; track repairer's tools.

Rolling stock: locomotives, tenders; passenger coaches; freight cars; separate parts of above; automatic brakes; train signalling apparatus; engine houses; shops for construction and repairs; snow plows; apparatus for taking various observations; dynamometers, self-registering apparatus; laboratories.

Management: time tables; distribution of rolling stock; cleaning and disinfection; signalling of train-men and various systems for assuring the safety of traffic; passenger department; tickets, ticket cases, posters, tariffs; freight department; tariffs; methods and equipment for checking and handling baggage and freight.

2. Other railway systems.

Rack, cable, elevated, sliding railways; movable platforms.

Permanent way: motive power or motors; rolling stock.

3. Street railways. Various types of tracks upon different kinds of roads; switches and crossings; turn tables: wyes and loops for turning; implements for track laying, cleaning, etc.

Cars drawn by animals: locomotives and automobile vehicles; rolling stock for street railways operated by mechanical traction; braking appliances; equipment for using stored power (hot water, compressed air, electricity, etc.

4. Special methods of transportation, similar to railways.

Transport of ships over railways.

5. Bibliography.

Statistics, special maps, and various publications relative to railways.

Merchant Marine Exhibits will be located in a different building, (the "Palace of Navigation"). Small exhibits in this class can, however, come under this plan for collective exhibit if desired and will be properly installed and cared for in their proper location.

AWARDS.

Collective exhibits receiving an award will have the name of each participant inscribed on the diploma, and each participant will receive a diploma.

The awards to exhibitors in the contemporary Exposition, and to the collaborators, will be issued in the form of diplomas, signed by the Minister of Commerce, Industry, Posts, and Telegraphs, and by the Commissioner-General. They will be divided into the classes following:

Diplomas of Grand Prize.
Diplomas of Gold Medal.
Diplomas of Silver Medal.
Diplomas of Bronze Medal.
Diplomas of Honorable Mention.

At the conclusion of the reading of the report of the Committee on Paris Exposition, upon motion of Mr. Condron, a unanimous vote of thanks was extended to the gentlemen enumerated in the report read by Mr. Modjeski.

ADDRESS OF ONWARD BATES, RETIRING PRESIDENT.

The by-laws of the Society require that at the annual meeting, its President shall make a report of the condition of the Society and shall present an address. The condition of the Society is exhibited in the reports already made by its Secretary and the chairmen of Committees. This meeting is an object lesson expressive of the Society's condition, and you cannot look around this room without being made aware of the prosperity of our affairs. The Secretary's report shows the membership in the Society to be greater than ever before. Our meetings during the past year have been well attended, and great interest has been shown by the members who were present. The Journal of the Society makes an excellent showing when we consider how busy our members have been during the past year. It contains some very good papers, and although we could not secure as many as we desired because our members were too busy to write them, they have been doing a vast amount of work worthy of description, which will furnish subjects for papers in the future.

The affairs of the Society have been well managed. We have had frequent meetings of the Board of Direction, and its actions have been harmonious. All of its members were busy men, and we could not do as much as we would like to have done, but a great deal has been accomplished, and the different members of the Board have made personal sacrifices to promote the business of the Society. Our prosperous year is due to the interest taken by the members in general, to the devotion of your officers and in a large measure to the efficient and faithful services rendered by your Secretary.

In my inaugural address last year, I had to thank the Society for conferring on me the honor of election to its highest office. I wish now to thank the Society for the support which it has given to its Board of Direction. This

has been to me a very pleasant year in all of my association with the officers and members of the Society, and I can have no better wish for our successors than that these conditions may continue.

In the Secretary's report, the names are given of our deceased members, who were called from us during the past year. In each instance there must be individuals here who feel with respect to some of those who are gone from us, a direct personal loss, and I wish to speak in behalf of the Board of Direction of one among them whom I knew best, Mr. Ferdinand Hall. Mr. Hall was zealous and devoted to the interests of this Society. His counsel was valuable to his fellow members of the Board, and we feel that in him we have parted with a friend as well as with a faithful and competent officer.

This I believe is the 30th Anniversary, or rather the completion of the 30th year of the Society's existence. We have on this occasion a special desire to hear from our old members, both the charter members and those who belonged to the Society in its early years, many of whom are present with us at this meeting. To secure their interest we sent letters to them inviting them to be here and to tell us something of the early life of this Society. Some of them are now present with us, and the others have sent us replies, wishing the Society success and expressing their sympathy with its objects and with its officers. In deference to them, it will be becoming in me to make my remarks short so we will have ample time to hear from them.

I now have the very pleasant duty of presenting to you our new President, Mr. Ambrose V. Powell. (Applause.) I wish to say that you might have hunted the Society over and not have done better than you did in electing Mr. Powell, and placing as the head official of the Society, one who has upon every occasion shown his interest in its welfare, and who has already done a great deal of hard work in its behalf.

When I went into office I did not find any gavel or any special instrument of discipline, but I managed to worry through the year and keep this body in order by using my knuckles as a gavel. It has occurred to me that it would be proper for the Society to have a gavel in view of any possible future contingencies, and I determined to present my successor with this little instrument, which, in order to be appropriate, I had turned from a piece of timber which had been in a bridge about 50 years, thinking that its age should command respect from the audience. I now present the gavel to Mr. Powell with sincere wishes for the prosperity of the Society under his administration, and with the hope that he will be able to pass it on to his successor without any serious wear from usage.

Mr. Ambrose V. Powell: Mr. President, and Gentlemen. I accept this emblem of authority, thanking you, Mr. President, for it and the kind words accompanying the gift, and you, gentlemen, for the great honor which I have received at your hands.

Some time ago, before the ticket was made up, I was asked by one of the gentlemen having to do with the entertainment this evening, what I would do to make the annual dinner pleasant in case lightning should strike my way. I answered, eat heartily and keep quiet. Possibly this did not affect the result of the election, but the fact that it was made unanimous would seem to indicate that the jest was taken in earnest, was in fact taken as a pre-election promise of good behavior for at least one occasion. Some of you may be familiar with pledges of candidates and the performances of those individuals after election; this is only one more instance of the same old kind. I am on my feet and the program reads "Address by the President elect," but as "address" is defined by Mr. Worcester to mean "salute," gentlemen, I salute you, hoping that as we are compelled to carry the burdens of two centuries the coming year, our pleasures and profits may be multiplied an hundredfold to correspond. Gentlemen, again I thank you.

The charge of the exercises of the evening was then given into the hands of Mr. Theo. L. Condron, as toastmaster, who offered the following

INTRODUCTORY REMARKS.

As has been already announced, we have completed thirty years of the life of the Western Society of Engineers. If I mistake not, the Society has one year that was a year and a half long. Am I right, Mr. Morehouse? There seems to be a question whether it was a year and a half or six months; there was an odd period. The original organization was formed about the middle of the year, and the reorganization was made the middle of one year to commence at the beginning of the year following, or in January. Consequently, there is a period when it was "neither hay nor grass."

It is our pleasure to have with us this evening a number of the original charter members of the Civil Engineers' Club of the Northwest. I might call attention at this point to the program that is lying before you, and to the fact that on the last page of that program is a list of the members of the Civil Engineers Club of the Northwest. I therefore introduce to you,—but I do not believe there are a half-dozen here who need an introduction—to the past-secretary of the Society, Mr. L. P. Morehouse, for twenty years Secretary, and I will ask him to tell us something of the minutes of '69.

MINUTES OF THE CIVIL ENGINEERS' CLUB OF THE NORTHWEST.

By L. P. Morehouse.

Mr. President and Gentlemen: I have the honor this evening and the pleasure of standing before you as an author. Not many of you, perhaps, are aware that I claim distinction in that line. In fact, I was not aware of it myself until recently, but as an author I have been asked to come here this evening and read to you personally some extracts from the book which it is said that I wrote a great many years ago. Upon examination of the matter I find that there is such a book and I recognize the handwriting, and I must confess I am an author. I shall have the great pleasure to myself—let us trust it will be a pleasure to you—of reading some extracts from a work which I wrote in the year 1869, which was announced in a card which I received from the Committee of Invitation, as the "Minutes of the Civil Engineers' Club of the Northwest, for 1869." That book I have had kindly exhibited to me. As I say, I recognize it and with your permission I will read you some very brief extracts in regard to the early history of this Society.

It may strike you as a little singular that these notes should be read, but I am reminded of the story of the visitor who was being shown the relics in a certain church in Ireland, and as he went from one room to another he was shown in one, a skull. Upon inquiry he was told that it was the skull of Saint Patrick. After awhile in another room he was shown another skull and he asked the guide, "Whose skull is that?" "That is the skull of Saint Patrick." "Oh, but you showed me the skull of Saint Patrick in the other room." "Oh, yes, but this is the skull of Saint Patrick when he was a boy." So you have listened this evening to the reports in regard to the present Society, Saint Patrick when he was a man; now I am going to take you back a few minutes and show you Saint Patrick when he was a boy, and there may be some little interest in the matter.

I find the first entry is to the effect that—perhaps I had better read it just as it stands. This is page 1, gentlemen, Civil Engineers' Club of the Northwest. The author's name is not given, but I have already stated it, so you will know what it is about:

"In pursuance of an invitation to them and to other civil engineers, from Col. R. B. Mason, the following named gentlemen met at No. 13 Dickey's Building, Chicago, on the evening of Tuesday, May 25, 1869: R. B. Mason; I. C. Chesbrough; H. A. Gardner; Chas. Paine; L. H. Clarke; William Bryson; K. F. Booth; Wm. H. Clarke; Max Hjortsberg; George C. Morgan; A. L. Van Meenen and L. P. Morehouse."

I believe, gentlemen, that I am the only person present this evening of those whose names I have read. If there is any other gentleman here who was then present I shall be very glad to meet him.

"The meeting was called to order by Col. Mason and, on nomination, offi-

cers for the evening were appointed; Mr. Gardner, Chairman; Mr. Morehouse, Secretary. Mr. Payne stated the object of the meeting was to organize an association of civil engineers. W. H. Clarke spoke upon the same subject and upon motion of Mr. Paine, after remarks from nearly all present, it was

"Resolved, That we, the civil engineers of Chicago here assembled, now form a club to be called The Civil Engineers' Club of Chicago.

"On nomination of Col. Mason a Committee composed of Messrs. Paine, Hjortsberg and W. H. Clarke was appointed to report at the next meeting a plan of organization and operation.

"The above mentioned Committee was authorized to extend invitations for membership in the club to other engineers in the Northwest.

"The meeting adjourned to meet in the same place the second Monday in June at 8 p. m."

Now I cannot read to you all there is in the book. That is not very thrilling that I have already read, but it is a statement of fact and therefore possesses some little interest. On page 4 I noted in looking the book over there was an item that might be interesting:

"Messrs. Paine, W. H. Clarke and Katte were appointed a Committee to consult with the Chicago Academy of Sciences, Chicago Historical Society and any other parties in regard to securing the temporary use of a suitable room."

So that we were looking about for a place to meet with other kindred societies about as soon as we were born. On page 5 I find that in the month of October so few members were present that the meeting did not organize and no business was transacted, showing that the interest had not been maintained at fever heat up to that time. On page 6, I think it is, I find something that seems to me of considerable interest, showing the way in which this Society in its infancy was able to provide papers for all its meetings, a method not unique, possibly, but certainly very complete as it is outlined here, and which a number of us know was more or less—rather less, perhaps—successful for a number of years in obtaining papers:

"Mr. Paine proposed the following resolution—"

I should have stated that Mr. Charles Paine at that time was division engineer on the Lake Shore & Michigan Southern Railway, and was really the father of the Society, as the invitation issued by Col Mason as the most representative engineer at that time in the city had been gotten up by Mr. Paine and was issued at his request. Mr. Paine always took a deep interest in the Society, and still continues that interest to a considerable degree although it is many years since he resided in Chicago.

"Mr. Paine offered a resolution which was unanimously adopted.

"Resolved, First: That the Secretary is hereby directed to prepare an alphabetical list of the names of the members of the Club, and that each member be required to present to the Club in his turn a paper upon some professional subject to be chosen by himself, one paper to be read at each meeting.

"Resolved, Second: That any member whose turn it may be to supply a paper shall be notified thereof by the Secretary as soon after the monthly meeting which precedes his turn as may be, and such member shall be responsible for the reading of the paper at the next monthly meeting; and if for any cause he shall be unable to read a paper it shall be incumbent upon him to procure a substitute who will read one, and to notify the Secretary of the name of the substitute for the meeting."

I would call upon all the succeeding secretaries for their testimony as to how faithfully that has been carried out on the part of the Secretary and how faithfully observed by the members. At the present time, I think, Mr. Chairman, you might have about five hundred papers on your list if that had been lived up to.

On page 7 I come across an item which is of considerable interest, to the effect that a paper on "Railroad Frogs" was read by Mr. John E. Blunt. That was the first written paper read to the Society, and Mr. Blunt has the honor of being the first of the many members who have presented interesting and valuable papers to the Society.

Upon the same page—this was in December—the Club was organized in May. In December we were in such a prosperous condition financially—I am very glad to hear the financial report this evening and to know that we have so much much money on hand, but in the early history, gentlemen, we were even better off than you are at the present time, because I haven't heard of any resolution like this being offered: in December, I say, it was

"Resolved, That the Secretary be and hereby is directed to suspend until further action of the Club the collection of the initiation fee provided for by the constitution." (Nobody had paid any initiation fee up to that time. I will further state that nobody had paid any dues up to that time. We were in a very prosperous condition.)

"Resolved, Second: That the yearly dues of each member for the current year be payable at the first regular meeting hereafter at which he may be present."

Now I have been asked frequently by persons who have looked over this book and seen the names of members—they ask "How about this name here? I thought he was a charter member, and yet he doesn't seem to have paid any dues until up to a certain time." But you will see that while we were all charter members who were on the list we didn't have to pay any dues until we came to a meeting. That may account for the fact that some of the meetings were very thinly attended, because at the first meeting that a man attended he was, as you might say, fined for being present. (Laughter.) But I think this is a resolution that it is not usual to find in the proceedings of societies.

On page 8 we seem to have run across a snag in regard to papers, because the Secretary read a letter from Mr. Robert Harris sending us his resignation as a member. After discussion of the matter, upon motion it was resolved that "the Secretary be directed to inform Mr. Harris that his name began with "H" and that a long time was before him until he would be called on for a paper, and that his resignation would not be accepted." (Laughter.)

On page 15 I seem to have made a note of something that is interesting. The Secretary stated that at the request of several members he had dircted a collation to be served at the close of the business meeting. "Upon motion it was resolved that the action of the Secretary be endorsed and he be empowered to pay for the collation." In those days, gentlemen, we had funds not only to pay for ordinary expenses, but for banquets like this without calling on the members at all. It seems to me we must certainly have been in a very flourishing condition when we could do this. We certainly didn't have five thousand dollars on hand, but we had enough for that. We seem to have had some money, because the Treasurer paid the bills.

A Member: You had a good Treasurer.

The Speaker: I was the Treasurer. (Laughter.) I will explain that we held our meetings at that time and for a considerable time in the club rooms of the Sherman House, which were very kindly given to us for that use, and so when the end of the year came around we thought it was a very proper thing to do to give a collation, as we called it, at the Sherman House, and give the proprietors the benefit of what they might get out of that as one way of paying our rent. So for several years we indulged in that practice and gave a collation to the members and satisfied our consciences by paying a moderate and reasonable sum to the proprietors of the Sherman House.

I would say in this connection that by referring to the financial statement in the latter part of the book I find that the gentleman who made the first payment in money to the Society was the gentleman who sits at my right tonight, Mr. Chanute. (Applause.) This first money payment to the Society, under the resolution I have read, to the effect that members should pay when they attended the first meeting, was promptly refunded to Mr. Chanute, he not having been present at the meeting. And as to the importance of that resolution, I find in the financial statement entries to the effect that the money was refunded to several gentlemen from out of the city who had sent in their money but had not been present at meetings.

On page 22 I seem to have noted something for which you will allow me to refer to my notes. Ah! there we passed the Rubicon. This was in February, 1871, about two years after the organization:

"The Secretary laid before the meeting" (and it was of rather a melancholy character) "the necessity of soon receiving a small sum to meet current expenses, and on motion of Mr. Chesbrough it was resolved that the members resident in Chicago pay at once to the Secretary the sum of Two Dollars on account of annual dues for the second year."

So you see we did not call on them for a very large amount of money at that time. I think that on that page I found a notice to this effect also, that Mr. A. Comstock read a paper, illustrated by drawings, on "Coal Mining at the Wilmington Mine." This was the second paper that was presented and I have the pleasure of seeing Mr. Comstock sitting at my right hand next to Mr. Chanute. (Applause.)

We are favored, gentlemen, in having with us tonight such representative gentlemen as Mr. Chanute and Mr. Comstock; one who first supported the Society by his financial contributions, and Mr. Comstock who supported it by his literary contributions.

There is only one more entry, gentlemen, that I think it is worth while to trouble you with, and if I can find it without too much trouble I will read it and with that will close the literary exercises which pertain to the present speaker. I will read these minutes in extenso, and if you see anything that you would like to criticise I should be very glad at the proper time of any correction,—hardly correction, because the minutes were approved at the proper time and it would not be proper after this lapse of time to make any corrections,—but criticism would be in order.

I would like first to read one entry that my attention was called to by Mr. Condron in looking over the book, which he thought was interesting.

"The meeting appointed for October 9, 1871, did not take place in consequence of the fire which the night before and that day destroyed the business portion of Chicago and the part of the city lying on the north side of the river."

That will fix, gentlemen, the date of the great Chicago fire, if it becomes necessary in the future to do so. Now I will read the minutes of the thirty-second regular meeting:

JANUARY, 1873.

The 32nd regular meeting of the Civil Engineers' Club of the Northwest was held on the evening of Jan. 13, 1873, at the rooms of the Chicago Academy of Sciences.

Mr. Cregier was called to the chair.

Reading the minutes of the last meeting was dispensed with.

Mr. Thos. J. Seeley was proposed for membership by Messrs. Potts and Williams, and Mr. C. Latimer by Messrs. Gardner and Carter.

The Secretary announced donations to the Club, from Col. D. C. Houston a copy of the Report on the North Sea Canal of Holland by General J. G. Barnard, and from Gen'l W. W. Wright a photograph of the Leavenworth Bridge.

The thanks of the Club were voted to the donors.

The Secretary read a letter from the President, Mr. Paine, tendering his resignation on account of his change of residence to Cleveland.

The resignation was accepted and the following resolution was passed:

Resolved: That we accept with deep regret the resignation of Mr. Charles Paine as the president of this Club, and that we tender to Mr. Paine our warmest acknowledgments of the service he has rendered the Club by the deep interest he has, from its origin, taken in its welfare and progress.

Mr. E. S. Chesbrough was unanimously elected to fill the vacancy caused by the resignation of Mr. Paine.

The Secretary presented a paper prepared by Gen'l W. W. Wright, descriptive of the proposed bridge over the Missouri river at Nebraska City.

The reading and discussion of this paper was postponed till the next meeting.

The following resolution was passed:

Resolved, That the Executive Committee be instructed to provide a room for the next meeting more convenient and accessible than the one in which this meeting has been held.

The meeting adjourned.

Now it seems to me, as I said, that those are very proper minutes. They seem to read all right. But I would like to explain to the members of the family—because I wouldn't say it to anybody else, of course; this is all amongst ourselves—that a more correct account in detail could have been written had the writer of the minutes desired to write them out in a particular vein. Those minutes, gentlemen, are founded on fact. The minutes which might have been written out were something like this. This was a time when the Society was without a room. It had been decided to change its place of meeting, as I might have read you in the minutes of the preceding meeting, to the hall occupied by the Academy of Sciences. This particular evening was a very stormy evening indeed. The wind was howling, the temperature was falling and the thermometers were breaking all over the city. When the Secretary went down to attend the meeting at the Academy of Sciences he was not able to find the Academy of Sciences at the number which had been given to him. The Academy of Sciences, in other words, did not materialize, and while he was wandering up and down Wabash avenue he met another member of the Society who was upon the same errand, Mr. D. C. Cregier, and Mr. Cregier was just as much in doubt as to the whereabouts of the place of meeting as the Secretary was. And presently another gentleman, Mr. T. J. Nicholl, made his appearance on the scene with his overcoat pulled up above his ears, and the three members consulted as to what should be done. The Secretary informed them it was necessary to transact some important business that evening. They were not able to find the Academy of Sciences' headquarters so they adjourned to a convenient doorway on Van Buren street where they were sheltered from the wind. The Secretary having all the papers and paraphernalia in his pocket announced to the other members of the meeting what would be necessary. Mr. Cregier was duly elected Chairman of the meeting. The Secretary was instructed to write out the proper minutes and elect the proper officers and the meeting was declared adjourned. Mr. Cregier asked the members to go around and get something warm. (Laughter.) I relate that to show how faithfully we kept up the organization of the Society under adverse circumstances, and I trust the same spirit in office has been passed along to the present officers and members, and will continue to be passed along, so that the Society, vigorous in its youth, will each year of its continuing existence, go on increasing in strength, vitality and influence. (Applause.)

Toastmaster Condron: You were all very much in doubt where the doorway led to where this important meeting was held. Fortunately, Mr. Morehouse made that clear. That reminds me of the meeting that I attended of the Milwaukee Engineers' Club a few years ago. They were not in a doorway, but they had a dumb waiter. They were over the doorway, in other words, and the meeting was very enjoyable and we discussed the paper,—the discussion was not entirely a dry one either.

Mr. Morehouse has spoken of Mr. Paine being the controlling spirit of the early organization. It is therefore fitting to read a letter that has been received from Mr. Paine by our President in response to the invitation to be here tonight:

Tenafly, N. J., December 30, 1899.

Mr. Onward Bates, President, Etc.

My Dear Sir: I feel much regret at being compelled to decline the gracious invitation which you have sent me to dine with the Western Society of Engineers.

It is gratifying to have seen so important results from a small beginning as appear in the present state of the Western Society, and I trust, as I hope, that its growth will continue as vigorous as heretofore.

Pray recall me to the memory of the old fellows who knew me in the Club, and assure them of my continued admiration and affection,—not yet impaired by time nor separation. Yours faithfully,

CHARLES PAINE.

Mr. Morehouse has also informed us that the first paper before the Civil Engineers Club of the Northwest was written and read by Mr. John E. Blunt, and so I might add that the last paper received by the Western Society of Engineers was from Mr. John E. Blunt, and I will also read that:

Chicago, January 1, 1899.

Mr. T. L. Condron,
2d Vice-Pres. W. S. E., Chicago.

Dear Sir: I regret exceedingly that I will not be able to attend the annual meeting tomorrow evening owing to sickness in my family.

With the best wishes for the continued success of the Club and a Happy New Year, I am respectfully,

JNO. E. BLUNT.

While I am reading letters it would not be amiss to turn to the letter that has been received from one whom many of us, almost all of us, know very well, and whose absence here is sincerely regretted this evening.

Madison, Wis., December 30, 1899.

Mr. Onward Bates,
President Western Society Engineers, Chicago, Ill.

My Dear Bates: Being able to sit up once more, and convalescing rapidly, I write to express my great regret at not being able to do my duty to the Society this last month. It was my plan to get out the report for the financial committee and attend all important directors' meetings. During the year I have felt that in my absence Mr. Condron would be pleased to look after the meetings, so that I have not felt much responsibility in that direction. This with my long (four months) absence East has resulted in my being a weak support for you.

I congratulate you upon your activity, and the success of your year's administration. My only regret is that I cannot be present January 2, and enjoy the good dinner of fellowship.

Wishing you a Happy New Year, Yours sincerely,

N. O. WHITNEY.

Toastmaster Condron: Mr. Blunt had expected to be here this evening and respond to the toast "The Chicago & Northwestern Railway in '69," but in his absence I take pleasure in calling upon Mr. Finley, our new Second Vice-President, who sits at my left, and ask him to say a few words to you.

Mr. Finley: Being the youngest member in point of years of service in the Engineering Department of the Northwestern Railway present here tonight, it is eminently fitting that he should be called upon to speak to you reminiscently of the period of '69 on the Northwestern Railway. However, I will take this opportunity of thanking the Society for the honor conferred upon me and not take up your time with further remarks as I see so many pioneers of the Society present who will speak to you more intelligently and interestingly than I could hope to do. (Applause.)

Toastmaster Condron: We have with us, by letter, another pioneer member, and before calling on any of those present I will ask your attention to the letter from Mr. Walter Katte:

Ardsley on Hudson, New York, December 30, 1899.

Onward Bates, Esq.,
President W. S. E., Chicago, Ill.

Dear Mr. Bates: It is indeed with most sincere regret, that I cannot be present on the 2nd prox. to join with you and fellow members of the Western Society of Engineers,to dine with them in celebration of 30th anniversary of the foundation of the "Society." It would have been a special pleasure to me, had it been possible for me to there meet the few remaining members of

the little "band of brothers" of the craft who met one evening in the old "Sherman House" nearly (or more I should say) than thirty years ago—"tempus fugit"—but few of that little band are now left as well as the noble host, that have so ably and admirably built up the Western Society of Engineers upon the foundation we then laid, little thinking then, to what grand proportions our modest efforts might aspire to and which have in thirty years grown to such a goodly and influential size. I should have felt an unusual pleasure in meeting you all around the "festive board" in the bond of brotherhood and for the sake of "Auld lang syne," but most unfortunately I have pressing business engagements next week which do not admit of postponement. I beg you will express for me to the Society the warm (though silent) interest I take in it and my highest aspirations for its continued prosperity and usefulness, and my high appreciation of, and thanks for, the courteous honor of their invitation; and for yourself personally I beg you will accept my highest sentiments of regard and esteem.

Very cordially yours,

Walter Katte.

Not so very many months ago we had the pleasure of listening to an address or lecture by an engineer who has generally kept on earth, although he has bridged rivers. But on this occasion he has soared to heights above and told us about flying machines. Now flying machines have not come into general use as yet, so we may ask Mr. Chanute to say something to us about the Kansas City bridge in 1869.

THE KANSAS CITY BRIDGE IN '69.

By Octave Chanute.

Mr Chairman and Gentlemen: It was to the Kansas City Bridge, or, rather, to my connection with it, that I owed the honor of an election to this Society. I remember very well how surprised and pleased I was when thirty years ago I received from my friend, Mr. Morehouse, a notice of my election. I was at that time on the frontier, at the jumping-off place where the population was just pouring into Kansas, and was endeavoring to bridge the Missouri river, which had a bad reputation. It was to the fact that I was endeavoring to carry on such work, which has since been performed so many times, that I owed, I think, the honor that I received and which brought me into the same Society with the distinguished men whose names have already been mentioned here tonight: Col. Mason, Mr. Gardner, Mr. Chesborough, Mr. Hjortsberg, Mr. Pope, Mr. Harris, Mr. John Newell, all of whom have gone from this world before me. I was at that time, as I say, on the frontier and rather unsophisticated. I was not used to city ways. But I was a member of other societies and I knew that the first thing that was always done was to take up a collection. So I remitted to my friend Morehouse, and I distinctly remember how surprised I was when my remittance was returned to me. It was against my experience entirely. (Laughter.) But I accepted the facts and upon my first visit to Chicago, which was months afterwards, Mr. Morehouse explained to me the peculiarity of the organization, so that I never offered to repeat the offense.

Now that you have mentioned the Kansas City bridge it has brought to my mind the recollection of a confession which I have long wanted to make, but which through indolence I have postponed from time to time until I have sometimes feared that I would pass off from this stage without having confessed the error,—an error which shows how easy it is to blunder. At the time we built the Kansas City bridge I felt very sure that we had placed all the important foundations directly upon the rock. All the river piers had been placed upon what we thought was rock as we had drilled into it for four or five feet; so while we knew that under the pivot pier there were pockets of sand, we never questioned but we had reached the original bed-rock of the river. Seven or eight years later the foundations were all examined and the diver who went down reported that there was a crevice under the pivot pier;

that he had found an opening about two or three feet wide and three or four feet deep which had enabled him to crawl partly under the edge of the foundation of that pier. He described it as a vertical seam, produced, as he thought, by an earthquake. A caisson of wood was sunk around it, in order to close off that crevice, without the slightest suspicion on the part of the men who did the work,—the American Bridge Co.,—that they had not sunk that caisson down to the rock. Some twelve years afterward further examination was made, shafts were sunk into the pier in order to explore its construction, tunnels were driven, and afterwards another caisson of iron was sunk down, intended to go to the rock. Upon carrying out that last work it was discovered that the pier, which we all thought rested directly upon the rock, did not rest upon solid bed-rock at all; that it was fifteen feet away from it; that below the rock which we had drilled into, which consisted of very large slabs apparently slid down from some higher elevation, there was a vein of sand, another vein of clay, and then a vein of soap-stone. But the peculiarity was that this should only have been found upon further investigation after twenty-five years had passed, and that the pier, which, in the meantime, so far as I know, had not settled or given any trouble, did not rest upon bed-rock. So here is a case in which no less than three sets of engineers had been mistaken in their belief concerning the foundation of that bridge. I instance this blunder and I make this confession simply that we all may be on our guard against making similar mistakes.

One thing more I want to tell you before I sit down. I have just returned from Europe and I there learned that great preparations are being made to entertain American engineers if they come over next summer. The French Society intend to throw open their headquarters to American engineers and to make special provision for their comfort and pleasure. The English Institution of Civil Engineers intend to do the same thing. They expect to place their house at the disposal of the American Society of Civil Engineers to hold its annual convention, and they told me that they would be very pleased indeed if a large number of American engineers were to come over this summer. Therefore, such of you as can afford the time, will be assured of a hearty reception on the other side if you go over. (Applause.)

Toastmaster Condron: I am going to change the programme as printed a little because of the very important happening that has taken place today,—a happening that is one of the most important in its bearings on the health and welfare of this community that has probably taken place in several decades; and I bring up the last sentiment on the programme next as later it is to be followed by some remarks from Commissioner McGann whom we have with us, and I believe it will give him a cue to tell what he knows about this end of the ditch. I therefore ask Mr. Isham Randolph to tell us something about the opening of the drainage canal. (Applause.)

OPENING THE DRAINAGE CANAL.

Isham Randolph.

At a late hour I was asked to be ready to say something at this meeting. Some thirty years ago, when I started out from old Virginia, amongst the boyish treasures which I brought away was a poetry machine. Now that machine has lain unused for very many years. When it was brought to my notice on Saturday last that this was to be an anniversary meeting, celebrating the organization of the original Engineers' Club of the Northwest, I bethought me of that old machine. Thinks I, "I will look it up and see if I can grind out something." I got it out Saturday night and the old thing was pretty rusty,—worked very hard indeed. I invoked the poetic muse, but she didn't come very readily, and, thinks I, "Well, New Year's Day will be a holiday and I will endeavor then to get it all straightened out." The first thing I knew I was ordered to be in Joliet bright and early New Year's Day to meet certain commissioners who were going to pass upon this self-same ditch of which mention has been made. I spent the day with them and far into last night with the diggers of the aforesaid ditch. At 5 o'clock this even-

ing I got over to the Technical Club and I found my poetry machine there with my valise. I divided the time remaining to me before the meeting of the Club between taking a bath and washing off the soil of the new canal, and the work on this poetry machine.

I put into the hopper the names of all the original members of the Club, but somehow or other they did not strike the train exactly and when they came out they didn't rhyme. But I will give you what the machine worked out as far as it went, and then I will come to the ditch:

THIRTIETH ANNIVERSARY, WESTERN SOCIETY OF ENGINEERS.

My comrades! we who here tonight
Commemorate, in Time's swift flight,
Three decades of its measured span,
Since men we honor, true and wise
Did our organic life devise
And gave it scope and plan;

The Plan, the scope, the natal thought
And all the after years have wrought,
Attest the wisdom, deep and sound,
Of those who forged with kindly hands
The links which form the social bands,
By which our craft is bound.

Who were these men? their names, their deeds?
What wrought they to supply the need
That pressed upon mankind?
What builded they in wood or stone?
And are their children proud to own
The names they left behind?

Go read our archives, ye who ask—
Which you will find a pleasing task—
And as ye dwell upon its roll
You'll mark on each successive name
One who has earned and has some fame,
And know you read from honor's scroll.

Chicago bows when Chesborough's called;
No old world city proud and walled
Can claim a son more dear;
'Twas he who bored the Lake below,
Through tunnelled galleries led the flow
Of waters cold and clear.

I would to heaven in worthy verse
I could the claims of each rehearse
Who then the charter signed,
And formed the nucleus for the band
Who, going forth in this broad land
Our greatest works designed.

They built our railroads, miles on miles,
The riven rock and earth in piles
Smoothed down, and shaped to be
The highways for those thundering trains
Which bear our ores and golden grains
From mines and prairies to the sea.

Our rivers, broad and deep, they span,
And 'mongst the grandest works of man
Are bridges whose prodigious strength
Is born in brain and skillful thought
Before the stubborn steel is wrought
And fitted to the structures length.

From such beginning have we grown
'Till early love is proud to own
Our badge and nâme and powers,
And we have men whose deeds shall be
Still nobler as the years shall flee
O'er this dear land of ours.

Isham Randolph.

Chicago, Jan. 2, 1900.

The machine ran down just then. (Laughter and applause.)

The little barrier of earth which kept back the flow of Lake Michigan from that great ditch which we have dug was broken about 10 o'clock this morning and now the waters are running through the sluice-way from which the channel is to be filled. The sills of the gate at Lockport are fifteen feet below Chicago datum. The closed gates will hold the water up to the level of Lake Michigan, even though that level should reach five feet above datum. This channel must be filled full to the brim before the work can be completed. At Campbell avenue there is a dam across the channel made by dumping earth to protect the bridge work which has been in progress there for some time past,—that work which for its magnitude and speed of completion challenges comparison in the way of rapid sub-structure construction. It will take about eight days to fill the channel. After that the barriers which I mention will be removed and the full flow of 300,000 cubic feet of water per minute can be passed through this channel toward the Mississippi.

Chicago has done all this, and with this magnificent achievement added to the many which she has wrought before, what we now hope for is that this great government of ours will take hold where Chicago has left off and complete her enterprise, and that her ships, and her boats, may pass from Chicago to the Gulf and onward through that channel, which we hope shall be within the near future, to the cities of the world in western seas.

Gentlemen, the story of the canal has been told too often for me to dwell upon it here, but I cannot drop the theme without speaking of those who have gone before, and those who have held up my hands in this mighty work. Those who preceded me planned wisely and well. There has been but little that I could change or better, and in the mighty work I have had the strong hands and fertile minds of many faithful helpmates. Without their loyalty I could have accomplished nothing, and I wish to make a record of it here.

Within a very few days I hope you will mark a noted change in the condition of Chicago River. That stream which has smelled to heaven for so many years is about to be cleansed and pure waters flow where vile streams have festered for so long. Gentlemen, I thank you. (Applause.)

Toastmaster Condron: We have the pleasure and the honor of having with us tonight a representative of our city government, a representative of that department of our city government which comes in closest touch with the engineering profession; and I am sure that all who have been brought into contact with Commissioner McGann have appreciated how strongly he is endeavoring to increase the municipal improvements of this great and somewhat crude city of ours. It is therefore with the greatest pleasure that I introduce to you tonight Honorable L. E. McGann. (Applause.)

(See Mr. McGann's remarks on page 1.)

Mr. French: Mr. President, allow me to break in on the proceedings for a kind of question of privilege. If I were a member I should make a motion that the rest of the speeches be omitted. We have had the great pleasure of hearing these speeches by the men who are concerned with these great works,

and we who are guests are aware that we are invited as a matter of sentiment to figure in the capacity of ancestors and give a sort of venerable character to the proceedings. We are surprised to see to what young men the interests of the country are committed, and we should be allowed to stand up in a row and be exhibited, and then allowed to go—some of us having suburban trains.

Toastmaster Condron: There are those who undoubtedly will have to go earlier, but they will be the losers. We want to hear something from those who are here, and I want at any rate to introduce to the younger members of the Society of Engineers, Mr. French, who was one of the pioneers of 1869. The programme, I know, seems long. It has been well filled so far, and yet I hope that before the evening closes we will have an opportunity of hearing, not only from Mr. French, but Mr. Greeley also; but as Mr. French is probably in somewhat of a hurry I will ask him to tell us something about his experiences. I believe we would enjoy it more if he would turn from engineering matters to matters of art. We have talked shop a good deal, and we do not often have with us one who is a devotee of art.

Mr. French: Mr. President, Mr. Greeley's train goes five minutes before mine. (Laughter.)

Toastmaster Condron: Then we will postpone the art and talk a little more shop. Mr. Greeley was assigned a sentiment for this evening and he came over to my office and said it was an exceedingly dry sentiment and he wished to moisten it, and he therefore suggested "The Ante-Fire Surveyor." I suppose that the fire dried everything, and that the surveyor was pretty dry until, like some others, he stepped "in a doorway."

Mr. Greeley: Mr. President, it is really too late for me to speak to you tonight. The question of surveying does not interest engineers. I am simply a surveyor and never had a right to be a member of this association. I was a member twenty-five years ago; however, I resigned my membership five years ago, and I think you must excuse me from saying anything and allow me to retire.

Toastmaster Condron: Now, if Mr. French will just say a word to us so we can all become familiar with his face.

THE BOARD OF PUBLIC WORKS IN '69.

By W. M. R. French.

Before Mr. Greeley goes out, I should like to quote a remark of Mr. Charles Paine, the first president of the Club. He said he had known many surveyors who claimed to be engineers, but no engineer except Mr. Greeley who merely claimed to be a surveyor.

It is too late, gentlemen, for speeches this evening. I am known to you, if I am known at all, in connection with the Art Institute, and appear, no doubt, to you to belong rather to the ornamental class of society; but there was a time in '69 and '70 when I was engineer in charge of the construction of sewers for the South Division of Chicago and was a useful and well-disposed citizen. (Laughter.) My association with the eminent engineers who were then here is a matter of most agreeable reminiscence. The Board of Public Works at that time—I am not certain that I can recall the members of the Board of Public Works of '69, but I find in my memory the names of McArthur and Carter and one or two more that I can almost think of, who were very much my seniors, and who had the good sense to employ men of eminent capacity to support them in their work, such men as Mr. Chesbrough and Mr. William Clarke, who did great service to this city. With them associated in this Club were those names which have been mentioned so many times this evening, Mr. Paine, Mr. Hjortsberg, Mr. Greeley, Mr. Morehouse, Mr. McClure,—men of the highest class; of character, of attainment, of breeding; with whom it must be a satisfaction to any person to have been associated.

With the usual perversity of memory, it is the trifling things and not the important things that remain in my mind in connection with my service with the city. I remember on one occasion one of my fellow engineers see-

ing an Irish laborer—probably at that time a foreman—laying out a form on the sidewalk, perhaps a template for a sewer, which resembled a geometrical diagram, spoke to him and said:

"Can you tell me, Dave, what the sine of an angle is?"

Dave replied, "The sine of an angle, sor—the sine of an angle is the perpendicular let fall from the extremity of an arc upon the opposite deeameter. Can you tell me, sor, what the co-versed-sine of an angle is?" (Laughter.)

And I know the story to be true because the Irishman told me so himself. He ultimately became a contractor of some note; said he had been educated in the public schools of Dublin.

Of course I could go into these aged reminiscences at length, but I will shorten my speech. I should be most gratified if you would come to the Art Institute and make yourself known to me, that I may show you what has diverted me from the profession of engineering. I was born with a proclivity to fine arts, which I resisted until I was thirty. It has now taken possession of me and I will play the part as well as I can. I thank you, gentlemen. (Applause.)

Toastmaster Condron: We have had a good deal of solid information and a good deal of serious talk. I called up one member of the Society over the telephone today and told him we would like to have a speech from him tonight. "Oh," he said, "that is unnecessary, I think," and I used the illustration that a dinner of the Western Society of Engineers without a speech from him would be like a glass of wine without the wine, and I believe that Captain Hunt can explain to you why I should make such a statement.

PAST PRESIDENTS.

By R. W. Hunt.

Mr. Toastmaster and Gentlemen: Listening as you did to the eloquent words of the Commissioner of Public Works there was emphasized upon your minds the grandeur of our city, and when a few moments later a gentleman stated that in order to reach his home in that same city at a reasonable hour it was necessary for him to leave about 11 o'clock, you can imagine better than any words can describe how great our city is. (Applause.)

I remember well, as many of you do, the year that it was my honor to be the President of this Society, that we entertained some foreign guests, and on our program for their entertainment was a ride down that great avenue of which we are all so proud and through the southern parks, coming to the Washington Park Club where an entertainment was given them. They thought it was a very good entertainment. Some of the gentlemen, outsiders, had expressed the desire to see some of our decidedly material works, namely, the stock-yards, and we were trying to keep them away from the idea, as that was not the part of Chicago that we were leading the foreign engineers and people of culture to think of as our greatest attraction. However, it was insisted upon that they should go, and so it was arranged that before this entertainment was over a special train would leave the siding at Washington Park and take those to the stockyards who wished to go. Mr. Harrison was the mayor—God bless his memory!—of the city at that time and was presiding. It fell to my duty to interrupt the proceedings by announcing that this trip would take place. In my usual green and innocent way I stated that the trip would take place, but that those who wished to remain and return to the city would find trains ready at the completion of the banquet. The Mayor immediately said he hadn't the slightest idea where that man came from who just made the announcement, but he certainly was a stranger to Chicago because otherwise he would realize, and he wished the other foreign gentlemen who were there also to realize, that they were at that time in the absolute center of the City of Chicago. (Laughter.)

Mr. Toastmaster, following your lovely conversation with me over the telephone in which you did not give me the slightest intimation as to the sentiment to which you desired me to respond, I find that you have selected it and

had it printed. What lightning workers these Chicago printers are to get that program out after half-past five!

"To the Past Presidents of the Western Society of Engineers!" I feel, sir, that that is a very appropriate selection on your part, because you have picked out the youngest of them all to respond to the sentiment. I am honored by the appointment and feel it this evening when I look around me and see such a large assemblage. If you keep this Society running years enough you will have even a greater attendance, because the Past-Presidents never miss coming to a banquet, and I find almost enough of them here tonight to account for this glorious assemblage. When I call the names of Horton, Artingstall, Williams, Cooley, Herr, Randolph and Bates—modesty prevents my going further—are you not proud of your past history? And captained all by Chanute, the man who gave the first cent, the first dollar to this great and now successful Society. Let me here, gentlemen, pay a tribute to Mr. Chanute. Perhaps you recall that following those glorious days when the Society met in a sheltering doorway and had a kind friend, subsequently a president, to open that door—I don't believe they went a step away from it; I think that same door was opened to get in where there was something warm—following those days we had a little trouble over financial propositions and it became necessary for some people to put their hands in their pockets and put up money to keep this Society going. And I wish to say tonight that the spirit was then manifested that gave the first contribution, and we had a greater one from your Past President, Mr. Chanute. (Applause.)

Another thing struck me as being very significant, gentlemen, of these pre-historical reminiscences which we have had tonight, that the first paper, the first thing of absolutely substantial, mental food presented to you was a paper on "Frogs." Well, I find that our last one tonight of a substantial character was a contribution on "Ducks." So that during your varying fortunes and posing before the world as enjoying only absolute intellectuality—as a Society depending on brains—that you are still keeping in view the physical side of life.

I don't wonder that Mr. French told us a moment ago that he had deserted the science of engineering, or rather, the profession, to take up art, and then illustrated it by a question on angles. He has told where he is now, making himself useful as he has always, to the city and to his community and to the age. He simply deserted angles for curves. If you don't believe it remember that monument which was placed on the Lake Front last summer under his direction for a few short weeks. (Applause.)

Gentlemen, we all have the right at the beginning of this great century—and I have the sanction of the Church in so stating—to congratulate ourselves upon the status of our Society. We have passed through troublesome times, and it certainly must have done many of your hearts good tonight to hear of the balance in the bank which was drawing interest; and to be assured by the reports of all our officers and committees of our substantial and prosperous condition.

We have all been worried a little about the troubles of our English cousins. Following our late war our hearts went out in gratitude to our friends in Great Britain, who were our friends when we needed them. But still they had to a small extent a patronizing way. They said, "Of course, you are good people over there. You ought to be; you came from us. But you didn't know exactly how to conduct a war. You fought among yourselves all right—well, it wasn't to be expected. You hadn't any standing army and you never had gone outside of your own country, or at least not off your own continent, to conduct a war." We must admit we quarreled a little with some of our own administrative officers; some of the boys talked about not having ice on the ships; others that the water was not as good as it ought to have been; and some of them that the general cuisine was not of a tempting character. Of course, some who had experiences earlier in our history thought perhaps they were a little hypercritical, but they didn't know, things had changed so much since their war days. However, we accepted the condem-

nation bestowed upon us by our English cousins, and looked sorry. Their war came and, to our very great surprise, our mentors have proven absolutely that they did not know any more about conducting a war, against a civilized foe outside of their own country, than their poor cousins across the Atlantic. And what is more, they took the same kind of beef that we had cried our people out of office on, to feed their soldiers in a country quite as hot as where we tried to make ours eat it; and again, that their first defeat was because American mules kicked at being shot at by Boers. (Applause.)

However, gentlemen, we all try to be without prejudice or partisanship on either side, and as much as we love our cousins across the waters, it is pretty hard to sympathize absolutely with their going into a free country to enforce demands upon a free people. Still, most likely, we do not understand the situation. We deplore the war and we pray to God the sweet angel of peace may presently spread its white wings over that far away country and that the principles of the congress at The Hague, so strenuously upheld by England and ourselves, may prevail.

Gentlemen, I thank you very much and trust that this year will give to our Society even greater prosperity than we have enjoyed in the past one. (Applause.)

Toastmaster Condron: If you will pardon me for reading one more letter, I promise this shall be the last:

Chicago, January 2, 1900.

Mr. Onward Bates,
President, Western Society of Engineers,
Chicago, Ill.

Dear Sir: I have your very cordial invitation to attend the annual meeting of the Western Society of Engineers next Tuesday evening, at the Grand Pacific Hotel, and it grieves me to state that my health at present does not permit my attendance. It would afford me the greatest of pleasure to be present on this occasion, to greet the few older members who are still remaining with us, and to make the acquaintance of those bright men who are in the future to take our place and direct the affairs of the Western Society of Engineers. We have witnessed in recent years what new blood and new life has done towards the elevation of the Society. This is markedly shown in the able publications that have issued from the members of the Society, and it is not too much to predict that it will remain, as it now is, the leading engineering society of central North America.

As above stated, it grieves me much that I will be unable to be with you on the evening mentioned.

Yours truly,

D. J. Whittemore.

We have received regrets from quite a number of other older members of the Society besides those from whom letters have been read. There is a letter here from Mr. O. B. Green, who is unable to be out this evening; Mr. Paige, Mr. B. M. Newman, Mr. George C. Morgan, and Mr. George H. Frost, all of the class of '69. We also have a telegram from Mr. Fred Davis wishing us well; a letter from Col. H. G. Prout regretting his inability to be here and wishing us a happy new year; a letter from Richard P. Morgan who expected to be with us until the last moment when he was kept back by sickness.

The program we have here includes one whom we always enjoy hearing and he always has something very recent and new to tell us about. Certainly, there is no member of the Society who keeps more abreast of the times than the one I am about to call on. It is true with him, as has been said, that a thousand years is but a day, but nevertheless he keeps up to the times. I wish therefore to introduce—no, it is not necessary to introduce—Mr. Ossian Guthrie.

DEEPENING THE ILLINOIS & MICHIGAN CANAL (1865 TO '71)—PRELIMINARY WORK RELATING THERETO IN 1864.

By Ossian Guthrie.

I had contemplated making some comparisons between the preliminary work relating to the deepening of the Illinois & Michigan Canal and that relating to the Chicago Drainage channel, and to this end had prepared a somewhat elaborate paper in that relation; but considering the lateness of the hour and also the fact that we are all familiar with the elaborate preparation of the engineers of the drainage channel, water-shed maps, contour maps and other data almost without limit, I will confine myself to tooting my own horn by reading one letter and making a few comments thereon, leaving the comparisons for you.

Illinois & Michigan Canal Office,

Secretary's Office,
Lockport, December 22, 1864.

Ossian Guthrie, Esq.,

Dear Sir:—Will you do me the favor to give me approximately the length and average width and depth of Chicago River (main river and both branches), which is made foul by the city drainage.

Also, your opinion of the quantity of water which you could raise per minute, including the whole season of pumping, with our "works" at Bridgeport when put in the best possible order and kept so.

Also, the expense, taking the prices of the past season as a basis of doing this.

I, of course, have some opinions about what we could accomplish by what we have done, but no one understands exactly what the "works" can be made to do as well as yourself.

The leading men of your city are beginning to inquire "what they shall do to be saved" from being stunk to death, and we would all better be looking up facts. Yours truly,

Wm. Gooding.

P. S.—What would it cost now to erect works like our own, estimating roughly?

I regret that I am unable to give you my report on the subject matter of the letter, but suffice it to say that not more than one week was spent in collecting the data required and that investigation was all that was made, preliminary or otherwise, by which to determine the capacity of the proposed channel. Tributary water-shed and rainfall were absolutely ignored, as was also the effect of the Des Plaines River. Obviously, little money was wasted on preliminary work, but in carrying out the project a large sum was wasted. The deepened canal was opened in July, 1871, at a time of extreme drouth and a comparatively high stage of the lake—the most favorable condition—and for the time being seemed to be a success. This work cost $3,400,000 and after the effect of freezing and thawing of two or three winters upon the banks sloped 1 to 1, proved almost a complete failure. As soon as possible, pumping was substituted for gravity flow, the pumping establishment costing $260,000, and an annual operating expense of about $60,000. Strange as it may now appear, his was one of the most popular attempts at public improvement Chicago has ever entered upon. Conceived in the fall of 1864, an enabling act was passed the following winter and contracts were let in the spring of 1865. I opposed this scheme, for stated reasons, which were supported by what appeared to be incontrovertible data. However, in this relation I received a letter from Wm. Gooding, the projector, of which the following is an extract:

"Your letter of yesterday is received, and your explanations about pumping are entirely satisfactory.

"I must confess, however, that your explanations in regard to your course in the other matter—the deepening of the canal—are not satisfactory. * * *

"I am not disposed to discuss this question more, but will simply say that such engineers as (here naming ten eminent civil engineers) with many others who have long been engaged in their profession, differ with you very decidedly in opinion."

The word "opinion" as here used does not seem to be justified, for the reason that I had based my conclusions on certain statements, the truth of which was never questioned, and these data sustained, the question had but the one solution.

Toastmaster Condron: Gentlemen, we have come to the end of our program; the evening has grown late, and while there are many here whom it would be a pleasure to hear from, I would hardly know where to stop if once outside the limits of the program; therefore a motion to adjourn will be in order.

A motion to adjourn was put and carried.

SPECIAL MEETING—17th of JANUARY, 1900.

A special meeting (the 416th) of the Society was held in its hall on Wednesday evening, 17th of January, 1900.

President Ambrose V. Powell in the chair and 42 members and guests present.

This not being a meeting for business, the Chair called upon Mr. Geo. M. Wisner, Asst. Engineer of the Sanitary District of Chicago, who was present at the opening of the Drainage Canal to give a statement of the details of what took place at that important event. Mr. Wisner's talk was full of interest and enjoyed by all present.

The first paper of the evening was on the Design of a 175-Foot Counter Balanced Swing Bridge by Mr. Albert Reichmann and was followed by one on the construction of the same bridge by Mr. W. A. Rogers. Both papers were fully illustrated with lantern slides. Discussion succeeded the reading of these papers in which Messrs. Liljencrantz, Bley and Reichmann took part.

Mr. G. P. Nichols rose and referring to the interesting account given by Mr. Wisner of what occurred at the opening of the Drainage Canal said, "To a large extent the work on the Drainage Canal has been done under the auspices and direction, I think entirely so, of the members of the Western Society of Engineers; and today having been practically the culmination of this great work with such a high degree of success it seems fitting that the following resolution should be offered:

Whereas, this day the Bear Trap Dam of the Controlling Works of the Main Channel, of the Sanitary District of Chicago, was lowered, allowing the waters of Lake Michigan to flow toward the valley of the Mississippi, thus formally opening the Drainage Canal, the construction of which has been constantly under the direction of members of the Western Society of Engineers, therefore be it

Resolved, That the congratulations of this Society be and hereby are extended on this occasion to the present Chief Engineer, Mr. Isham Randolph and his talented corps of assistants, and to all of the other Engineers that have been identified with this most important engineering work during the years of its construction, and be it further

Resolved, That these same congratulations be extended to the Honorable President and members of the Board of Trustees of the Sanitary District of Chicago.

REGULAR MEETING—7th of FEBRUARY, 1900.

A regular meeting (the 417th) of the Society was held in its Hall on Wednesday evening, 7th of February, 1900, President Powell in the chair and 31 members and guests present.

The minutes of the previous meeting were read and approved.

The Secretary reported for the Board of Direction the receipt of applications for active membership from James J. Harding and Chas. H. Davis; for associate membership. Hugh M. Wilson, and for transfer from Junior to active membership Messrs. T. J. Klossowski, Marion E. Thomas, and Henry H. Lotter.

There being no other business the Chair announced as in order the discussion of Mr. G. B. Springer's paper on Electrical Underground Construction. Messrs. Bley, Ziesing, Springer and Artingstall discussed the question of the feasibility of a subway or tunnel to carry electric and all other lines.

The Secretary then read a written discussion on the Discharge Measurement of the Niagara River at Buffalo, N. Y., prepared by Mr. E. E. Haskell of Detroit, Mich., and this was followed by Mr. H. P. Boardman who was present and read a discussion he had prepared on the same subject.

Mr. J. H. Warder exhibited a meter for measuring rate of running water which had been rated by Mr. Haskell and a general discussion was had as to the reliability of such a meter under various conditions, the effect of friction, difficulties met in rating meters, etc.

The Chair then called upon the Secretary to read in the absence of the author a paper on "Railroad Preliminary Survey by Stadia," prepared by Mr. J. H. Lary, C. E.

Mr. L. A. Nichols thought that in stadia work it was hardly possible to get along with only two men, and suggested four men as being necessary to accomplish satisfactory progress, in which opinion Mr. W. F. Keating coincided. There being no further discussion the meeting adjourned.

NELSON L. LITTEN, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchanges and in completing valuable volumes of our files.

Since the last issue of the Journal we have received the following gifts from the donors named:

Commissioner of Labor. Sixth Special Report, 1893. The Phosphate Industry of the U. S.
Seventh Special Report, 1894. The Slums of Great Cities.
Eighth Special Report, 1895. The Housing of the Working People.
Ninth Special Report, 1897. The Italians in Chicago.

The New Panama Canal Company, Paris, France.
Technical Report.
Report of the Commission.
Technical Notes.
Atlas of the Panama Canal.

Report Nicaragua Canal Commission, 1897 to 1899, Text and Tables.
" " " Maps and Profiles.

Institute of Mechanical Engineers, England. Proceedings, July, 1899.

Metropolitan Sewerage Commissioners, Boston. Main Drainage Works of Boston and its Metropolitan Sewerage District.
Eleventh Annual Report of the Board, ending September 30th, 1899.

Institution Civil Engineers—London—Vol. 1 Minutes of the Proceedings of the Institution C. E. 1836-47.

Michigan State Board of Agriculture. Eleventh and Twelfth Annual Reports Experiment Station, 1898 and 1899.

Bureau of Foreign Commerce, U. S. A. Consular Reports November and December, 1899, February, 1900.
Exports declared for the U. S., 1899.
Merchant Marine of Foreign Countries.
Special Consular Reports—Vol. XVI—Part I. Tariff of Foreign Countries—Europe.
" " Vol. XVI—Part II. Tariff of Foreign Countries—America.
Disposal of Sewage and Garbage in Foreign Countries.

Massachusetts Institute of Technology, Annual Catalogue for 1899-1900.

Railroad Commissioners of Connecticut. 47th Annual Report, 1899.

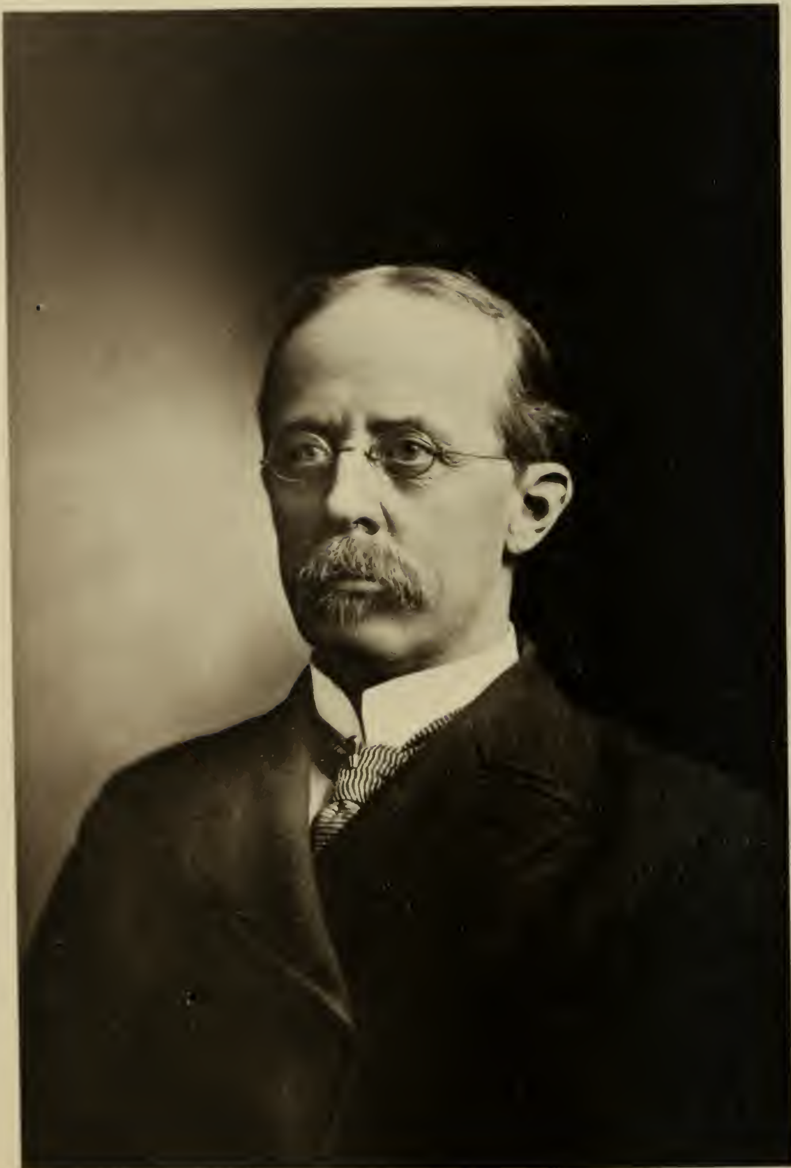
American Society of Municipal Improvement. Report of 2nd, 4th, 5th and 6th Annual Conventions, 1895, 1897, 1898 and 1899.

Ontario Land Surveyors' Association. Proceedings 7th Annual Meeting, February and March, 1899.

Geo. M. Ames, City Engineer, Grand Rapids, Mich.—100 Copies Miscellaneous Periodicals.

Boston Transit Commission. 5th Annual Report, 1899.

Interstate Commerce Commission. Preliminary Report on Income Account of Railways in the U. S., June 30, 1899.



President, W. S. E., 1900.

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LXXXIX.

ARE PRESENT METHODS OF TRAIN PROTECTION ADEQUATE?

By C. E. Davis, M. W. S. E.

Read March 7, 1900.

The multiplicity of train accidents constantly occurring, and the causes assigned for them, lead an inquiring mind inevitably to this question: "Do the so-called safety appliances meet the requirements of a constantly increasing train movement, and if so, why the accidents? And if they do not meet the requirements, where are they deficient, and what is needed to increase their efficacy to such an extent as to prevent the every-day occurrence of railroad accidents?"

It is safe to say that the services required of railroad employes, especially those connected in any way with the movement of trains, are of the most exacting nature; and their duties, even the most trivial, must be done with promptness and accuracy.

In no other line can the mistakes of an individual result in such serious consequences as in that of railroad employes; and, this being the case, it naturally follows that any safeguard thrown around them must be of the best, and capable of fulfilling the requirements of this most exacting service. To employ men or train them to perform the simplest of routine duties so that they will never make a mistake is impossible, because "he who never makes a mistake is something more than human." Therefore, any safeguard for the protection of railroad trains should be of such a nature as to prevent the mistakes of human agency.

Are our present appliances designed on this principle, and if so, do they accomplish the desired result?

It is true that checks and counter-checks are multiplied to prevent the displaying of a false signal to the engineman.

Take for instance our interlocking plants whose levers are so interlocked that a clear signal for conflicting route cannot be given at the same time and any attempt of the tower man to do so results in his being promptly reminded of the attempted error by finding the lever locked. Checks are also used to prevent the apparatus, if out of order, from giving a clear signal.

It is argued that gravity is an ever present, never failing power at the service of the signal engineer and all signals are counterweighted on the danger side so that the breaking of any of the connections will result in the signals showing danger.

In block signals, as in interlocking, checks are employed to prevent the signal man from making errors. He must get permission from the next signal man, in advance, before admitting a train, and in some cases this is supplemented by an electric lock which the train when passing out of the block must operate before he can clear his signal to admit another train. This same idea is embodied in the automatic block signal; gravity is employed to carry it to danger and the electric circuits which operate it are all arranged so that any derangement or the loss of current from any cause, will result in the display of a danger signal. All this is done to insure the giving of a proper signal at all times to the engine driver, or, to put it another way and more correctly, to insure against the apparatus becoming deranged and showing a clear signal when there is danger ahead.

It seems to be assumed that if the apparatus displays the proper information the engineman will always observe and obey it, he never making a mistake. But he is human, and why not, if possible, throw some safeguards around him and prevent him from making mistakes as well as other employes?

It is common practice to place in the track at interlocking plants a derailing switch, so arranged that when the signal is at danger, the derail is open and the train disobeying the signal would be derailed. This in several states is made obligatory before trains will be allowed to cross another road without first coming to a full stop. The arguments advanced in favor of the derail are first, it is better to derail a train than allow it to collide with another, and, second, that the derail has a good moral effect on the engineman and causes him to look more carefully for his signals. It is hard to appreciate this second argument when we stop to consider that a collision is likely to result in a far greater bodily injury to the engineman than would a derailment, and the disobedience of the signal must almost inevitably result in one or the other.

In these days of rapid travel, the old-time method of compelling each train to come to a full stop before passing a crossing will not answer, and some safe method of allowing them to pass at reasonably high speed must be found if not already provided.

On every hand is a demand for more rapid transit in both freight and passenger service, and this demand must be met, and with safety to traffic. If present methods are inadequate, new ones must be found.

The annals of railroad accidents are full of cases of mistaken signals, failures to see signals, and forgotten orders on the part of the engineman; and when we stop to consider the conditions under which he operates, we are forced to the conclusion that the only wonder is that accidents are not more frequent. An engineman

is working against time from the instant he starts his train until he arrives at his destination. To illustrate: We might tell a mechanic that he is required to drill three hundred holes in a piece of iron each day, and he would accomplish the result very easily; but if we should say, "You must drill one hole each two minutes, no more and no less," the man would become exhausted in a short time in consequence of the nervous strain under which he would be laboring. From each telegraph station the time of arrival and departure of each train is reported to the chief dispatcher, and the engineman's record is being made minute by minute, and on this record depends his reputation and standing with the company as an engine driver. Moreover, he frequently finds himself contending against the elements such as rains, causing a wet, slippery rail, heavy fogs, snow storms, etc. The desire to make schedule time is naturally uppermost in his mind. To be sure, he is frequently reminded, in the rules under which he operates, that the safety of the train must be his first consideration; but the fact that he has made his daily run for years, perhaps, without accident to his train, and that so long as he remains on his schedule he has certain undeniable rights, and if late, these rights are frequently lost, a desire to make schedule time becomes paramount, and he assumes risks and takes chances to maintain his schedule which endanger the safety of his train, and if he did not do so he would be something more than a man. Perhaps the best illustration of this that can be given is a statement made in conversation recently by a runner of a fast express train on one of the trunk lines. "My running time is sixty miles per hour; the block signals are one mile apart. Should anything happen to my injector, I could do nothing in the way of fixing it in a minute; and yet, if I devote one minute to it, I have passed a signal without seeing it. The injector must be made to work, the boiler must have water, I cannot stop, as I must make time; there is no alternative, I must neglect the signal. This is not true of the injector only, for other parts of the engine frequently require more than one minute's continuous attention, and there is nothing to do but give it to them and watch signals when I can."

It appears that in the design of safety appliances, considerable effort has been made to guard against mistakes on the part of those whose duty it is to display signals or give warning to moving trains by so arranging the apparatus that they can do but one thing, and that the right. Nothing is left to their judgment except that at an interlocked crossing a tower man might hold a first-class train and permit a second-class train to pass first, but this is a matter of discipline and does not in any way interfere with the safety of either train.

While great care is taken to see that the engineman, from whom, as above stated, the most exacting service is required, gets the right signal, it seems to be considered proper then to trust entirely to his judgment and proper action, unless we class the derail as a

check upon him. I, however, consider the use of the derail a very questionable expedient.

A careful study of railroad accidents and their causes has prompted this paper, and has forced me to the conclusion that there is something radically wrong in the methods of train protection now in use, and that the information the present appliances are intended to convey to the engineman cannot be relied upon to reach him under all conditions, and even if it does, he cannot be relied upon at all times to properly obey, as instantaneous judgment is frequently required, and this he cannot always exercise correctly.

It is therefore evident that some more reliable method that will be equally effective in fogs, darkness, storms and sunlight must be found, and this I do not consider beyond the reach of man's ingenuity.

DISCUSSION.

Mr. E. E. Russell Tratman—It seems to me that there is not much to discuss in the paper presented, as it is of such a very general character. The title as given on the announcement card implies that the paper is to deal with interlocking work, but the remarks made might apply as well to any other feature of railway service or equipment, and the paper certainly fails to give sufficient attention or credit to the methods and appliances in regular use in modern signaling practice. The author says it seems to be assumed that the engine man will never make a mistake, but this is entirely incorrect, as anybody familiar with railway service will know. In fact, at interlocking points the derail is put in specially to control a careless or reckless man who will "run for the crossing" in disobedience of the danger signal. The only definite point made, after all the remarks as to the dangers of railway service, is that the author considers derails to be objectionable, but he has no improvement or remedy to offer. In regard to the paper on the automatic brake-setting device, so much has been said about the inefficiency of signals and signalmen, that it may be well to remember that an automatic device of this kind does not necessarily meet all requirements. A criticism of automatic brake-setting devices recently made to me by a superintendent, was in regard to the possibility of failure of the brakes to act, a contingency which does arise more or less in practice. If the engineman cannot apply the brakes, or if the brakes are defective or partially fail on some of the cars, then the automatic device may be of little or no use, and, in the absence of a derail, there is nothing to keep the train from reaching the crossing. The automatic device may be an important auxiliary to the signal or interlocking equipment in certain cases, but should not be considered as a substitute for signals or derails, either in block signaling or at crossings. I am speaking now of ordinary railway service; but the same remarks apply to electric and elevated railways.

There is another point to be remembered. In using an auto-

matic brake-setting device, every engine, on the division at least, must be fitted with the necessary piping, trip, valve, etc. This may not be very important for one engine, but for a number of engines the cost of material, fitting up and maintenance might amount to a considerable sum. And though there may be but two or three interlocked crossings or junctions, every engine would have to be fully equipped, although they might not pass the interlocking plants on every run. Then, too, it cannot safely be assumed that a device of this kind will be infallible. In fact, with so many engine equipments it is quite as liable to fail as a derail, which is always under notice and subject to frequent inspection. A bent or broken trip will easily put the device out of operation. The device may serve the purpose at interlocking plants where the traffic is light and low cost of the plant is specially desirable, but, as already remarked, its proper function is that of an auxiliary to the signals and other features of the plant. For the real purpose of protection under conditions of heavy traffic, the automatic brake-setting device cannot safely be substituted for the derail.

Mr. Rowell—In reply to that I have to say that there were 168 derailments last year in the State of Illinois at interlocked crossings, of which there are but 168, and that in no case was a derailment caused by the failure of brakes.

Mr. Tratman—I do not see the significance of selecting derailments. There are other accidents besides derailments; collisions may occur and have occurred through failures of brakes.

Mr. Rowell—Repeating the statement made in my paper, "The automatic brake-setting apparatus has been in constant operation since 1893." I did not come here to give records, but am not averse to doing so. The five years record of the 36 automatic signals on the Metropolitan West Side Elevated road shows that the signals have stopped trains 85 times for each one million signal movements, which is about 50 stops per month, all of which were automatic and caused by the signals being out of order or disobeyed. The apparatus has been tested in all possible ways. Trains have been taken out numerous times to exhibit the working of the system, the motormen ordered to run as fast as possible and disregard the signals; the same thing has been done on surface roads and the brakes have never failed when applied by the Rowell-Potter apparatus.

Mr. de Berard—There is another answer to the statement as to brake failures. The fact that on all the passenger trains running over this continent there is no provision made for stopping except by the use of the power brakes, is evidence that power brakes are considered effective; and there is the further fact that no passenger train carries brakemen enough to handle it with hand brakes and that even those they do carry are never required to stand to the brakes when the power brakes are in operation, no matter how dangerous the point the train is approaching may be.

Mr. Reichmann—I wanted to ask the gentleman whether he knew anything about the interlocking systems in the old country; I think

they are employed more extensively there than they are in this country. I know in Germany they had very extensive interlocking systems.

Mr. Rowell—The gentleman is quite correct; they are employed to a much greater extent; in fact, in Great Britain no road is allowed to operate without a continuous block system, which is supplemented with fog pits. During foggy weather or storms which interfere with the engine driver's vision, men are placed in these pits to place torpedoes or shout to the engine driver, who is not allowed to pass without receiving proper information from the man in the pit.

WRITTEN DISCUSSIONS.

Mr. B. C. Rowell—The inquiries in the opening paragraph of the paper prompting this discussion are being brought more forcibly to the minds of the managers of our great railway systems and their patrons each day by the constantly increasing number of train accidents.

All great innovations or improvements that we are enjoying today have been established and brought to a success through a series of partial failures, and this perhaps is true to a greater extent with railroads than any other branch of industry.

Signal engineering is no exception to this rule. A vast amount of work has been done in this field in producing appliances designed for the safe conduct of trains which, though present requirements have proven to be partial failures, are yet of great value, because, in their failures, they point unerringly to the remedy.

Visual signals, in all conceivable forms, and operated by as many different methods, have been employed to obtain the one result, namely, to convey to the engine driver such information as is needed for the protection of his train.

Visual signals which depend for their efficiency upon the vigilance or the ability of the engineman to see them, or his correct understanding of their indication, have proven to be wholly inadequate.

If we needed further proof of this than the constantly increasing number of train accidents, we could point to the derail, the only necessity for which is the possible failure of the visual signal. We could also point to the torpedo, electric gong and other audible signals which depend for their efficiency upon being heard by the engineman, whose sense of hearing is perhaps more liable to preoccupation by other noises than is his sight to be obstructed by other objects.

The multiplication of these additions to the visual signal is an admission that the visual signal cannot be relied upon under all conditions, and the audible signal is added as a supplement to the warning given by the visual signal in the hope that both will not fail in the same instance.

Time and experience have proven that the warnings which depend for their efficiency upon an appeal to any one of the five senses of the engineman, are inadequate under certain conditions to be met

in railroad traffic. The office of any or all of these appliances is a request to the engineman, either to stop his train or reduce speed by the application of the brakes. Numerous instances are on record where both visual and audible signals have failed to attract the attention of the engine driver, resulting in accidents.

At crossings where the lesser of two evils must be chosen, the derail is employed. The efficiency of the derail is, however, an open question. In the State of Illinois there are 168 crossings interlocked. The Railroad & Warehouse Commissioners' Report for the year ending December 1st, 1899, gives the following record at these crossings:

Derailments caused by train running against signals, 125.
Derailments caused by towerman taking signal away from train, 8.
Derailments caused by defective interlocking functions, 7.
Derailments caused by defective track, 5.
Derailments caused by trains parting on same track, 1.
Derailments caused by defective rolling stock, 4.
Derailments where cause is unknown, 18.
Total number of derailments, 168.

It may be argued that should the derail be abandoned and trains be allowed to run these crossings without stopping, when the visual signal gave them the right of way, that a greater number of accidents and perhaps more serious ones, would have occurred. To this argument I take no exception save to say that any safety appliance under which this percentage of accidents can occur *is not a safety appliance* and ought to be abandoned.

We have in our technical papers and in our signal clubs a continual discussion of what the proper visual signal should be, the proper combination of colors to be used, and the positions they should occupy, all in the effort to make the visual signal do what, in the very nature of things, it never can do—convey a correct indication to the engine driver under all conditions. Even should we succeed in causing the visual signal to invariably display the proper indications, we have still to contend with carelessness, or momentary inadvertence, or, most dangerous of all, that recklessness which is almost inseparable from a long immunity from disaster. Moreover, an engine driver's duties are such as to render impossible his continual attention to the track ahead, and the elements frequently interfere, making it physically impossible for him to see or hear his signals. These are the great sources of peril most carefully to be guarded against.

It is evident from the records of railroad accidents and their causes that nothing short of automatic control of trains will give absolute protection under all conditions. To accomplish this result the following conditions must be met:

First, a good visual signal should be displayed as a guide and convenience for the engineman.

Second, the signal, when in the danger position, should automatically apply the brakes of any train attempting to pass it.

Third, it should be so constructed that if out of order it will stop all trains.

Fourth, any failure of a signal to go to danger as the train passes should result in stopping the train.

Fifth, signals used to indicate caution, commonly called distant signals, when indicating caution should apply the brakes of any train passing at a greater than the regulation speed.

Sixth, the flagman, sent back to flag a train, should have the power to apply the brakes of the train he is flagging.

All this should be accomplished in a durable manner and at reasonable expense. All these requirements are met by the system I represent.

The standard semaphore is the visual signal used in all our installations.

The automatic application of the brakes is accomplished by two instruments, one termed the engine machine, the other a track instrument. The engine machine consists of a vertical rod attached to the forward truck of the engine, the lower end being fitted with a roll and the upper end connected to a valve in the train pipe arranged so that any upward movement of the rod will result in opening the valve and locking it; around this machine is placed a guard and plow to prevent any obstruction that may be left beside the track from injuring the attachment or applying the brakes; the plow consists of a plate hinged at the top and suspended at an angle of thirty degrees from the vertical, the lower end extending below the bottom of the roll; the lower end of this plate coming in contact with an inclined plane will tilt upward and ride over it, but will brush other obstructions aside, keeping everything clear of the brake setting appliance.

The track instrument consists of two iron bars parallel to the rail in the form of toggle levers, pivoted at the ends and hinged in the center and raised and lowered by the rotating of a shaft, when raised forming a double inclined plane and when lowered being level with the top of the rail. Should an engine that is equipped pass these toggle levers when in the raised position, the vertical rod would be forced upward, the valve opened and the brakes applied.

These signals and track instruments are counter-weighted so that the breaking of any of the connections will result in the signal and track instrument remaining at danger. Gravity, however, is not implicitly relied upon, and should it fail no accident could occur, because a failure of the signal to move to the danger position as the train passes, results in the automatic application of the brakes. This is done because the most natural thing for any machine to do, exposed to the elements, as all railroad signals are, is to stand still, and a signal that remains at safety after a train has passed is not protecting the train; this is accomplished as follows: Two track

instruments are employed at each signal, connected rigidly together in opposite positions, one up and the other down, or one in unison with the visual signal and the other opposed to it. While the train is between these track instruments they must shift their positions or the train will be stopped. This is comparatively simple on double tracks, as all trains run in the same direction on each track and it is only necessary to connect the first track instrument in unison with the signal and the second one in the opposite position.

On single track roads this same principle is maintained by placing two automatic trips, one for each track instrument, inside of their respective instruments, that is to say, standing at the semaphore post the first object in either direction is the trip, the second is the track instrument; hence a train approaching from either direction must pass these instruments as follows: First, a track instrument; second, its trip; third, the semaphore; fourth, the second trip, and last the second track instrument. The signal, in going to safety, pulls both track instruments to safety and both trips into position to be operated by the first wheel of the train; and, in going to danger, pulls both trips away from the rail so that they will not be operated by the wheels of the train. An approaching train passes the first track instrument and immediately trips it to danger; this makes the necessary contact and sets the signal to danger. The signal in going to danger pulls the second strip away from the rail and the train passes on unmolested. Should the signal fail, however, to go to danger the first wheel of the engine would stirke the second trip, set the second track instrument to danger in front of it, and the brakes would be applied. The result of this construction renders it impossible to pass a signal at danger without stopping, impossible to pass a signal that is out of order without stopping, and impossible to pass a signal and not set it to danger without being stopped.

At distant or cautionary signals governing the approach to crossings, junctions, etc., where it is necessary to reduce speed, what is termed a speed-controlling track instrument is used. In this speed controller the well known principle of the pendulum is employed.

The track instrument is the same as those above described, set to danger by the action of the distant signal and to safety by the action of the pendulum. The pendulum is suspended at an angle, and locked in that position by the action of the track instrument going to danger, and unlocked by the approaching train, and, as it completes one vibration, it drops the track instrument to safety. The distance between the point where the train starts the pendulum and the track instrument is fixed, and it is only necessary to change the length of the pendulum rod to adjust it for any desired speed. The speed controller is adapted to work entirely automatically at any point where it is desirable to reduce speed, as well as in connection with the distant signal.

The engines once equipped with the automatic brake setting apparatus, all flagmen can be furnished with portable track instru-

ments, which weigh about eight pounds, and are as quickly and easily applied as a torpedo, and the stopping of the train is assured without depending upon his ability to attract the engine driver's attention.

To accomplish the results above outlined a sufficient quantity of power to move the signals must be obtainable at all points of the road where signals are to be placed. Each signal requires a maximum pull of one hundred pounds to ensure its proper movement under adverse conditions. To supply this force and distribute it at the ordinary cost of generating power, would not come within the bounds of the sixth requirement, namely, reasonable cost, but a cheap method of obtaining it has been provided. This is accomplished by means of what is termed the power storing machine, which is a cylinder having a central shaft. Inside of the cylinder is a series of flat coiled springs, one end of each spring attached to the cylinder and the other end to the shaft, the number and length of the springs corresponding to the amount of power required. On a concrete foundation between the ties is placed a fulcrum which carries a lever running at right angles to the rails, the short arm of which comes in contact with the base of one track rail, and the long arm carries a fulcrum on which rests a second lever, the short arm of which comes in contact with the base of the other track rail, and the long arm of this second lever connects by a link to a rachet ring on the cylinder so that any upward movement of the long end of this lever will rotate the cylinder and wind the springs, and this movement is obtained by the natural deflections of the rails as each wheel passes over them. The strength of the springs is exerted to rotate the shaft, to which the signal is connected by means of a crank and link. One half of a revolution of this shaft sets the signal to safety and the other half sets it to danger. The movement of this shaft is controlled by electric locks, the current for which is supplied by batteries, the amount consumed being one and a half amperes for about one-tenth of a second for each signal movement.

With the power thus obtained, which is ample for all practical purposes, automatic interlocking as well as automatic blocking, is made feasible and practical, and in fact, an automatic interlocking plant has been in constant operation in this State for the past eight months. It has operated continually through the winter and fully demonstrated its practicability for winter service.

Automatic block signals of the type above outlined have been in constant operation under very heavy traffic since 1893, and no accident has ever happened under their protection.

Quoting the closing paragraph of the paper under discussion: "It is, therefore, evident that some more reliable method that will be equally effective in fog, darkness, storms and sunlight must be found." It must be apparent to every one present that if the statements I have made here tonight are true, that "more reliable method" has been found and has proven its efficiency through a

period long enough to show that it will meet all the requirements under all conditions.

Owing to the limited time given to prepare this paper I have been unable to present illustrations for this meeting, but should it meet the approval of this Society I will be pleased to exhibit them at any future time you may desire.

Charles Henry Davis, C. E.—The paper by C. E. Davis, M. W. S. E., read March 7th, 1900, entitled "Are Present Methods of Train Protection Adequate?" brings out the following facts in connection with steam railroads:

1. The number of trains per track is constantly increasing.
2. The speed of these trains is also constantly increasing.
3. It is impossible to employ or train men so that they never make an error.
4. Railroad employes, in the operating department, must perform all their duties with constant promptness and accuracy.
5. Any error, of one or more employe, may result in serious loss of property and life.
6. Therefore, all means employed to protect trains against accidents, should be automatic and interlocking, so as to prevent those which arise from disobedience, carelessness, forgetfulness, or errors of "instantaneous judgment," etc., etc.

The paper clearly brings out that on many of our steam railroads it is now next to impossible for a wrong signal to be displayed, for we have:

1. Interlocking plants, so that a clear signal cannot be given for conflicting routes at the same time.
2. Signals are so arranged that if any part is out of order "danger is displayed."
3. Block signals are interlocked, so that a train passing out of a block must release the signal at the entrance of the block, before the latter can be set clear.

None of our steam roads, however, have any apparatus or device to automatically control the train should it not obey orders, either written or visual, unless the "derail" can be so considered. A device to injure or destroy a signal if improperly handled would be the laughing stock of the initiated; why not the same for the "derail"? The latter seems to be the only device, outside of the engineman's control, to make it impossible to disobey a signal; its use may result in an accident almost as costly to property and life as other forms of disobedience entail. On the other hand, our development of safety, interlocking and automatic devices to protect the signalman from possible error, has been extended until it can be considered almost perfect, when applied on roads where capital account it not the first consideration. A safety signal to be erroneously so set may necessitate the combination of errors or accidents to,

1, a preceding train,

2, its employes,

3. one or more signal men,

4. one or more signals and their entire systems of control and operation, and,

5. orders;

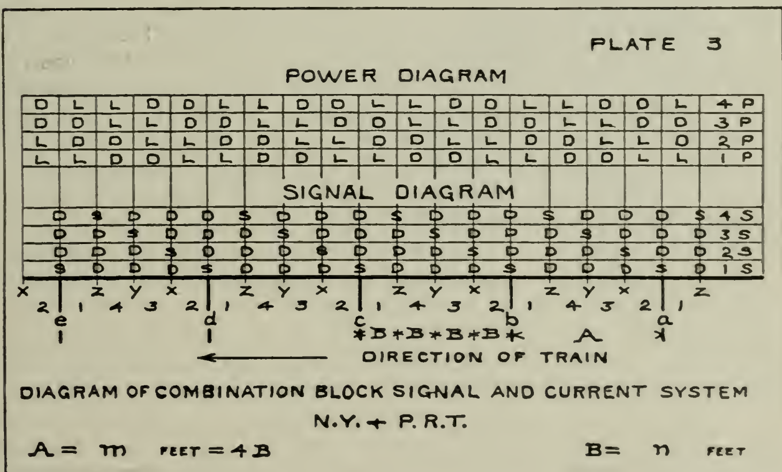
But the train is, finally, only protected by the engineman obeying the orders given, with but one automatic device to make it impossible to disobey, and that device, to say the least, is a clumsy, dangerous one. Various means of notifying the engineman, who has disregarded a danger signal, have been advocated and experimented with, such as torpedoes, bell ringing, whistle blowing, etc., but these all require his subsequent obedience to make them effective.

Sometime in 1890 the writer, then young in engineering experience, allowed his imagination to take full flight into the realms of the future high speed railroad; natural railroad laws were to be temporarily suspended or entirely relegated to a past era; "the greater the speed the greater the headway" was no longer to be an axiom. After some years of more thoughtful, calmer study and the collection of much data, he had the temerity to publish in 1897 a tentative outline of a proposed road between Philadelphia and New York, to be operated, without intermediate stops, in 36 minutes, thereby tending to make the former a suburb of the latter. (See Engineering Magazine for October and November, 1897, or reprint by the author). Close personal friends advised against such commitment. But the thought of many, more eminent predecessors, who had dreams (realized since by others) gave hope and courage to think that the Suez, Manchester and Panama Canals, the Brooklyn and Forth Bridges, the St. Gothard and Mt. Cenis Tunnels, Telephony, the X-Ray, Wireless Telegraphy, Electric Railways, Automobiles, Ocean Greyhounds, Empire State Expresses, etc., etc., were not the only developments from the past which have and will annihilate time and space, but that a system combining automatic, interlocking, signal and train control, placing human error beyond a possibility, would give the lie to the before mentioned axiom. After publication a prominent New York lawyer asked the opinion of one of our leading steam railroad presidents (both personal friends of the writer); the reply was, "he shows how not to do it"—a severe blow to a pride which is now living for its proper and just revenge in the conversion of said president. It may be of interest to consider the outline of the system then indicated, which was of course, to be operated by electric power:

"The signal system is of the greatest importance, and in some respects the most difficult to solve; on such a road, operating trains at 170 miles an hour, or 249.4 feet a second, equal to 2.853 miles a minute (14,964.4 feet per minute), our system of signaling must be perfection itself; it must be automatic, not only in giving a danger signal to the motorman, but in making it impossible for him to obtain power from the third rail when the signal is at danger, and, in addition must put on his brakes, if he fail to do so himself; further-

more, it must be of such a nature that any fault in any link of the system will throw everything to danger.

A suggestion of such a system is outlined in Plate No. 3. The heavy base line indicates the track; a-b, b-c, c-d, etc., are sections, each of a length not less than the distance which the fastest train would cover in the least allowable headway; while the smaller sub-sections, a-x, x-y, y-z, z-b, etc., are of such length that any train running at its maximum speed can stop within any sub-section without injury to the passengers. At "a," "b," "c," "d," etc., are signal towers, and at "x," "y," and "z" distance signals operated from the following tower. In the signal towers would be the power stations or sub-stations for distribution and control of the current to the third rail. The horizontal line of numerals indicates the first, second, third and fourth position of trains as they enter and pass through the



blocks controlled by towers "a," "b," "c," and "d"; the letters "S" and "D" in the first five horizontal lines show whether the signal at that point is at "Safety" or at "Danger"; while the numerals "1s", "2s", "3s", and "4s" are opposite the successive lines corresponding to the successive positions of each train, 1, 2, 3, and 4; similarly the letters "L" and "D" in the second five horizontal lines show whether that section is "Live" or "Dead," with corresponding reference numbers "1p", "2p", "3p", and 4p." The towers are interlocked, so that "S" cannot be shown at "a-x" until "D" has been shown at "b," nor can "S" be shown at "a-y" until the two sections each side of "b" are made "dead." It will be noticed that the section upon which a train is running and the one immediately ahead always have current, while the two sections directly following a train are always dead; there are also three danger signals behind

every train. The interlocking would be so arranged that signals behind a train could not be thrown to "S," until the train had passed out of the section, thus always maintaining signals and current connections as shown in the diagram. It will at once be seen that the capacity of a given track, in number of trains, depends upon four times the length in which a train can be stopped without danger to the passengers. The distance might have to be a greater multiple, six or eight. The system of signals suggested does not involve mechanism or methods not already found reliable and satisfactory; they are, however, applied somewhat differently. In the plan proposed, if a signal should go to danger, it would show the ordinary semaphore or light (at night), and at the same time it could have a device, to be operated from the passing motorman's cab, to give him warning. Setting the signal to danger would also throw into place a rod close to the third rail, somewhat like the safety rods used with interlocking signals and switches of today. This rod would have a long gradual incline approach, and project above the third rail sufficiently to throw up the sliding shoes past their center, so that the springs would hold them clear of the third rail, thus cutting off the power. The motorman's ampere indicator would also warn him. By a similar device, on entering a dead section, should the engineer have failed to apply his brakes at the first signal, a lever could be thrown, opening a valve similar to the present "conductor's valve," thus applying them automatically. Some such automatic combination must be relied upon to make the road safe, with no possibility of rear end collisions." (Engineering Magazine, New York, Oct. and Nov., 1897, or reprint by the author.)

Not daunted by such discouragements, various United States patents were applied for and granted during 1898, which, while they apply more especially to electrically operated roads, can nevertheless be adapted successfully to steam railroads. It might be mentioned, as of interest, that probably no sane "railroad" man (applied in the technical sense of steam railroad men) would have permitted his "prophetic" brain cells to indulge in such excitement, it being remembered that no reflection is intended upon their nerve or discretion. But, to a more serious view:

The author pleads guilty to lack of large practical experience to supplement a study of the operating departments of our steam railroads, but trusts the following may nevertheless prove of interest, although not displaying any thorough knowledge of the technical designations and "lingo" of the thoroughbred "railroad" man.

We shall divide the subject into

1st. Railway Signaling System, in which is described the signaling portion of a system allowing, with safety, high speeds and short headways, and 2nd, Combined Train Arresting and Signaling Mechanism, in which is described an automatic device to make it impossible for the engineman to pass a danger signal and in so preventing him, doing it without danger to the train or its occupants.

A third division dealing with "dead" and "live" sections on an electric road, is omitted here for some more opportune time.

1. RAILWAY SIGNALING SYSTEM.

This invention is a signaling system designed to meet the conditions of high-speed trains on railways and in such a way as to permit of the maximum number of trains consistent with safety to occupy the line.

It is especially applicable to railways whereon the trains are driven by electricity and at velocities which may reach or even exceed one hundred and seventy miles per hour.

It consists, broadly, in the combination, in a railway signal system, of a railway line, a series of signaling devices in proximity thereto, each device being constructed to exhibit a danger signal and a safety signal, and interlocking mechanism connecting each device with two or more immediately succeeding signal devices, the said signaling devices being constructed and arranged so that a given device cannot be set to exhibit a safety signal until it shall have exhibited a danger signal as many times as there are succeeding devices interlocked with it and unless said succeeding devices shall previously have been set to exhibit "danger."

The signaling devices may be of any kind capable of conveying the necessary information for the purposes set forth. The interlocking mechanism may be either mechanical or electrical, or both. The apparatus may be actuated manually or by any other means adapted to the purpose.

In Figs. 1 to 6 inclusive are exhibited visual signaling devices, each consisting of a four-armed cross pivoted at its center and provided with any suitable means for rotating it, so as to bring each arm of the cross successively into signaling position—as, for example, horizontally above and near the track. Three of the arms are suitably colored to indicate "danger" when exposed. The other is also suitably colored to indicate "safety." On the shaft of each cross is a barrel-commutator arranged to close certain circuits when the cross is in each of its four positions and also an electro-magnetic locking device which is included in certain electric circuits with other crosses. Suitable circuit connections are provided between the several signal-crosses and communication is made with a feeder-line supplying current, the construction and arrangement being such that inasmuch as the signal-cross can be rotated in but one direction it cannot exhibit a safety signal until it has shown a danger signal three times and also until three similar signal-crosses which are electrically interlocked with it and which immediately follow it shall have previously been set to exhibit "danger."

Fig. 1 is a diagram illustrating the system broadly and showing the positions of the signaling devices when the trains are occupying the line. Fig. 2 is a front elevation of the four-armed signaling cross and post. Fig. 3 is a side elevation of the same, showing the lock-

ing apparatus and commutator. Fig. 4 is an electrical diagram illustrating the interlocking of a signal-cross with the three signal crosses immediately in rear of it. Fig. 5 is also an electrical diagram showing the interlocking of each signal-cross represented with every other signal-cross in accordance with the connections shown in Fig. 4. Fig. 6 is an electrical diagram showing the interlocking of the four-armed crosses at the beginning of the line.

Similar letters and figures of reference indicate like parts.

Referring first to Figs. 2 and 3, A B C D are signal-arms connected to the hub E, which is supported upon the shaft F, journaled in the post G. The shaft F, and hence the four arms A B C D, may be rotated by any suitable means in one direction. Thus there may be provided a sprocket-wheel H on the shaft with a chain belt ex-

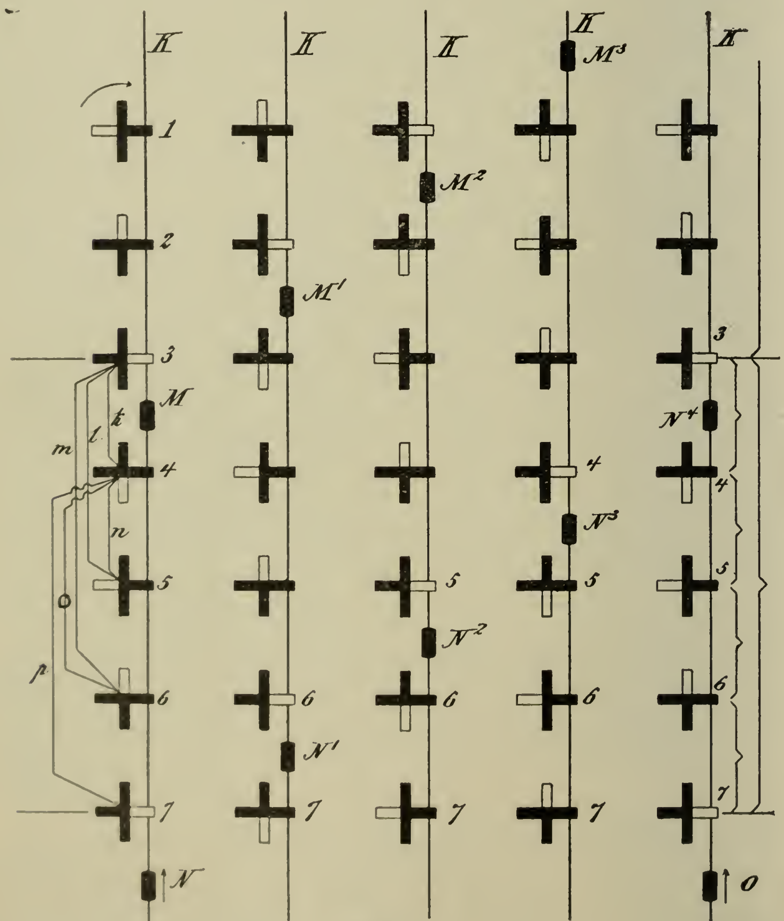


Fig. 1.

tending to a pulley H′, rotated by a crank I at the lower part of the post, so that by turning said crank the signal-cross A B C D may be rotated. By means of a ratchet and pawl J, also on the shaft F, the said signal-cross is prevented from being rotated except in one direction. This being the disposition of affairs, it follows as a matter of course that after one arm, as C, Fig. 2, of the cross has been displayed in horizontal position all of the other arms B A D must be moved into similar position successively before the arm C can be displayed a second time. The arms A B D may be painted red to serve as danger signals, and the arm C may be painted white to serve as a safety signal. The post G is to be located in suitable proximity to the railway line, so that the condition of the line ahead of the signal devices is indicated by whatever arm extends horizontally between the post and the track.

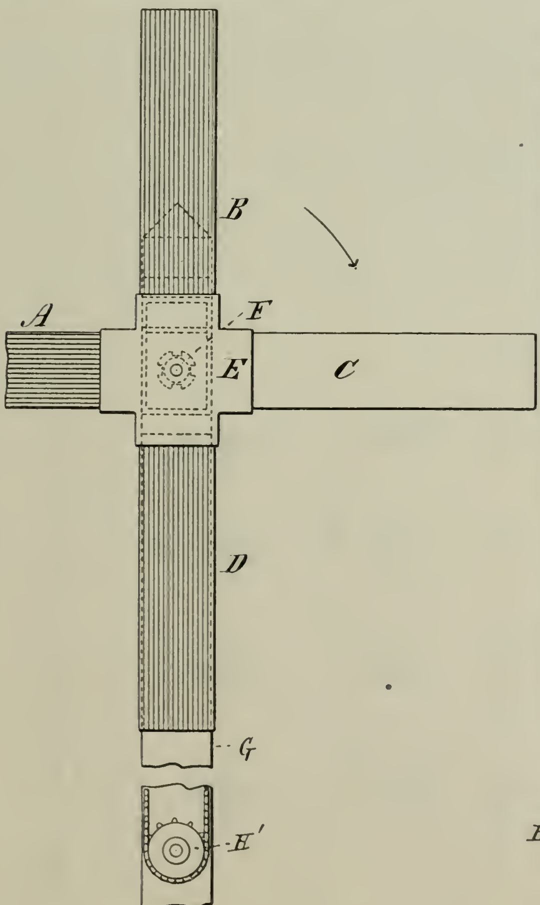


Fig. 2.

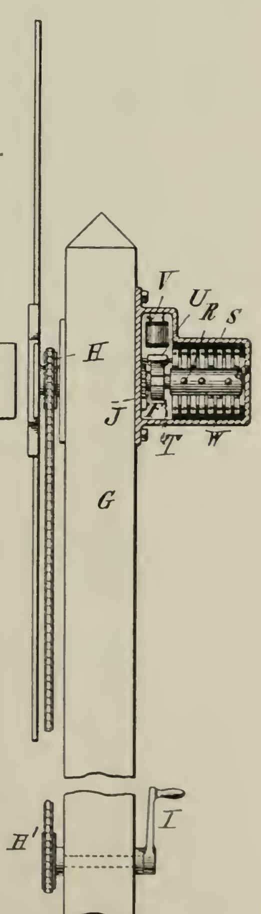


Fig. 3.

It is an obvious fact that the economical employment of any railway must depend upon the number of trains which simultaneously can be operated upon it with safety. It will also be apparent that as the speed of trains becomes increased the distance between them must be augmented and that therefore the "capacity" of a line for trains, so to speak, becomes diminished when the speed is augmented to a degree which, in comparison with that at present practiced on steam railroads, may well be regarded as excessive—such, for example, as a rate of one hundred and seventy miles an hour, which is perfectly attainable on a perfectly constructed electric railroad. Diminished capacity of a line for trains, and hence reduction in its earning power, tends to reduce materially the advantage gained by the reduction in time due to the increased speed. The invention is designed to reconcile these conflicting conditions, and it is organized in the following manner:

Having determined what shall be the maximum speed of the trains or vehicles which are to traverse the line and also having determined the space in which a given vehicle or train can be completely arrested by means of its brakes, a space or interval is taken as the interval which is to separate the successive signaling devices, which, as stated, may be crosses, as illustrated in Figs. 2 and 3. The fact is further established that the normal condition of all the signaling devices before any train goes upon the line or while the line is unoccupied by trains shall be that each and every one of them shall exhibit a danger signal. Reference to Fig. 2 will show that there are three positions of the cross in which it will show a danger signal—

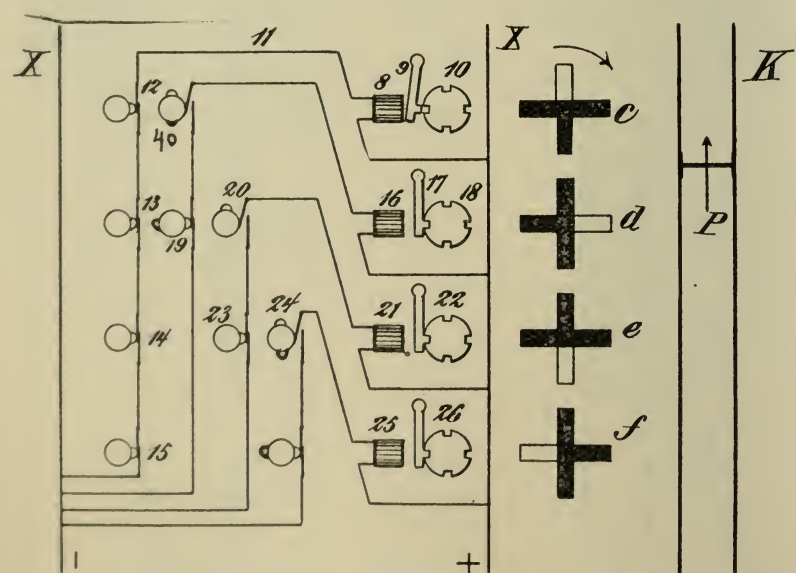


Fig. 4.

that is to say, when it exhibits either arm A or B or D in the place of arm C. The further fact is established that the normal condition of each signal before any train goes upon the line or while the line is unoccupied is to be such that a single change, or, in other words, a quarter-turn of the cross, will substitute the safety signal for the danger signal. Obviously, referring once more to Fig. 2, this condition is realized (assuming the cross to rotate to the right of the drawings in the direction of the arrow) when the safety signal arm C is in the position of the danger signal arm B. This condition is also represented diagrammatically by the four crosses *g h i j* in Fig. 5,

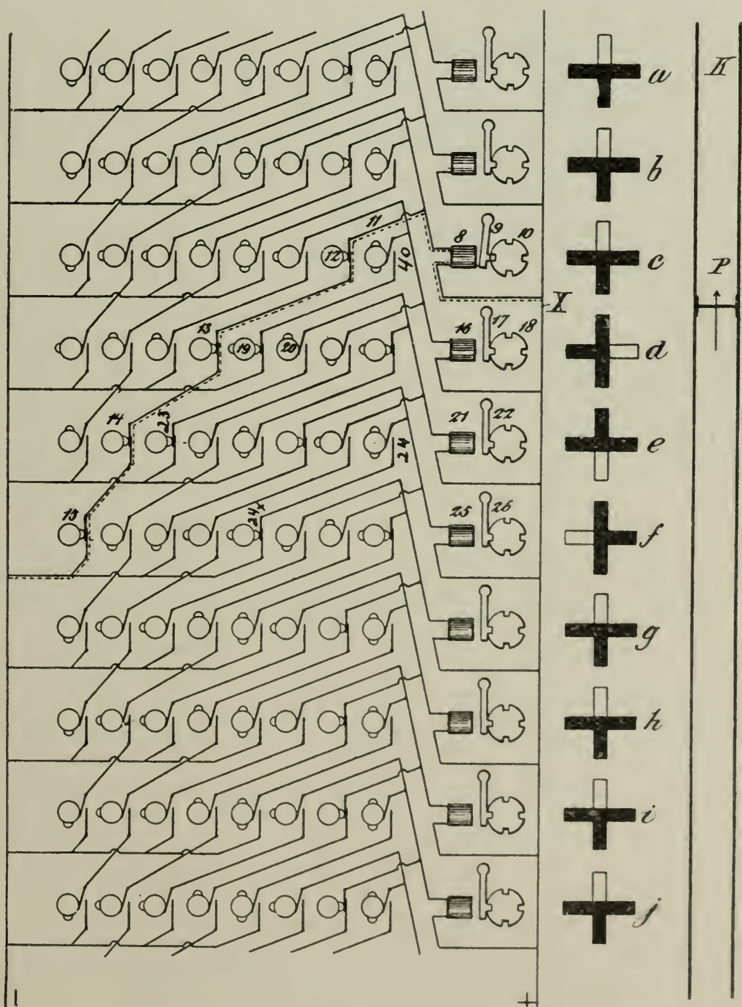


Fig. 5.

it being obvious that if any one of these crosses be rotated on its center to the right it will bring into horizontal position the white arm. Let us consider a train or vehicle moving over the line and passing the signal-crosses successively. As the train comes to the first signal station a safety signal is shown, which it passes and reaches a second signal station, where again a safety signal is shown and passed, and so on. After the train passes a signal set at "safety" that signal is set at "danger." Consequently as the train moves from one end of the line to the other it is constantly "preceded," so to speak, by a safety signal, while behind it danger signals are shown. Now referring once more to Fig. 2, where the safety signal C is shown displayed, it will be obvious that on the first quarter-turn to the right the arm B will have come into signaling position, and that on the succeeding quarter-turn the arm A will have come into signaling position, and on the next quarter-turn the arm D will have come into signaling position. Then and not until then will the cross have reached its original normal position which it had before the safety signal C was set, and which position is that which, as already stated, is represented in Fig. 5 at *g h i j*. In this way, therefore, by simply rotating the three signals in rear of a train ahead one quarter-turn each all three of them can be kept at "danger," and if these three signals are suitably interlocked with the signal which directly precedes the train then there may be not only a safety signal constantly preceding the train as it passes over the line, but three signals following that train interlocked with that safety signal in such a way as that that safety signal cannot be put at "safety" unless these three following signals are at "danger." Then we have still further this condition, that all other signals in rear of the train, except the three which guard it, are returned to their original danger position, so that the line is left ready to receive a second train, and in fact any number of trains which the line will accommodate.

To recapitulate, therefore, the signal-crosses are placed beside the railway line successively and separated by intervals, each equal to the space in which a train at maximum speed can be stopped by its brakes. These crosses are all set to show a danger-arm in the position represented at *g h i j* of Fig. 5, which is the position in which a quarter-turn or one movement of rotation to the right will bring the safety-arm into exhibit position. These signal-crosses are so interlocked and operated that a train in traversing the line is always preceded by a safety signal and followed by three danger signals, which three danger signals cannot be set to "safety." Finally, in rear of these three signals which follow the train the signals are in their normal or original condition. This will be more clearly understood by reference to Fig 1 of the drawings, which shows the line and the signals adjacent thereto in various successive positions. Beginning at the left, the railroad line is represented in all cases by the line K, the signaling-crosses by the numbers 1 to 7. The train M already on the line is represented in successive positions at M M′

M^2 M^3. The following train is shown just coming on the line at N and in its successive positions at N' N^2 N^3 N^4. Still another train is shown coming on the line and following the train N^4 at O. Considering the train N, which first receives a safety signal at 7, it passes to the position N'. The safety signal is shown at 6, and the danger signal at 7. It passes to the position N^2. Safety signal is shown at 5, and danger signals at 6 and 7. It passes to the position N^3, and safety signal is shown at 4 and danger signals at 5, 6 and 7. We have now reached the condition when there is a safety signal 4 in front of the train N^3 and three danger signals 5 6 7 in rear of it. It is obvious that the signal 7 in rear of the train N^3 has now been returned to its original position—namely, that shown at *g h i j* in Fig. 5—and if no more trains came on the line it would remain in that position indefinitely. Train N^3 would go on to the position N^4, preceded by the safety signal 3 and followed by the danger signals 4 5 6. But assume another train O follows. Then the signal 7 would be turned ahead a quarter of a revolution and the condition of affairs would be precisely the same as appears in front of the train N. The relations of the signals between the succeeding trains are clearly shown in Fig. 1 and need no further explanation. Thus it will be noted that after the train M^3 there are three danger signals, then a safety signal 4 in front of the train N^3, and then again three danger signals 5 6 7. Turning to the crosses shown in Fig. 5, there we have the condition of a single train on the line, with no following or preceding train. It will be seen that the signals *a b c*, as well as the signals *g h i j*, are all set in what I have hitherto termed the "original" and "normal" position and that the train represented at P and moving in the direction of the arrow has just passed the safety signal *d*, which safety signal is followed by three danger signals *e f g*.

It will be observed that we have here provided for three danger signals to follow the safety signal, the object being not merely to give sufficient space for the following train to be stopped by its brakes in case it should run past a danger signal, but a definite number of times that space, so as to adequately insure stoppage. For all practical purposes three times the space will probably be sufficient, but it may be decreased to twice the space, or increased to four or five times the space, making a corresponding modification in the number of signals displayed, or in the specific contrivance in the number of signal arms. Thus, to illustrate, and referring to Fig. 1, the train O may be stopped by its brakes in the space between the signals 6 and 7, also in the space between the signals 5 and 6, also in the space between the signals 4 and 5; but it has the entire space between signal 4 and signal 7 in which to be stopped.

We come now to the interlocking mechanism, whereby it is made impossible to set the signal in front of the train to "safety" unless the three following signals are set at "danger" and also impossible to set any one of these three following signals at "safety" so long as a safety signal precedes the train guarded. The interlocking me-

chanism which we illustrate for this purpose is here electrical; but it may be mechanical or constructed in any other way so long as the results sought are produced in similar manner and to the same effect and purpose.

The general idea of the interlocking is illustrated on the left of Fig. 1, where the signal 3 is connected by the interlocking mechanism represented by the lines *k l m* with the signals 4 5 6, while the signal 4 is connected by the interlocking mechanism represented by the lines *n o p* with the signals 5 6 7, and so on.

Referring now to Figs. 3 and 4, on the shaft F of the signal-cross is a commutator-barrel Q. This may be of insulating material and provided on its periphery with circuit-closing studs, one of which is shown at R. As each stud comes into suitable position it forces together contact-springs, and thus establishes circuit between these springs. The springs are shown at S in Fig. 3. Also on the shaft F is a locking-wheel T, having four indentations. U is a pivoted dog adapted to engage with said locking-wheel. This dog is the armature of an electromagnet V. The mechanism described is inclosed in a suitable box W and connected in circuit with feeder-lines X. The circuit arrangements will be best understood from Figs. 4 and 5. Here the commutator Q is shown developed as a series of successive circles, so as to exhibit the closing together of the different pairs of springs by the projecting studs thereon.

It will of course be understood that all the developed circles in line transversely across the page of the drawings with the center of the signal-cross *j* represent the positions of the circuit-closing pins or studs of the commutator belonging to that cross, and similarly all the circles in line with the signaling-cross *i* represent the positions of the studs of the commutator belonging to that cross, and so on, and the pins or studs of the commutator of each cross are arranged in a certain definite way with respect to the position of the arms of that cross in accordance as either arm A, B, C, or D is exhibited in signaling position.

What may be called the "unit arrangement" obviously involves interlocking of four successive signal devices, and this is illustrated in Fig. 4, at the moment when the train P on the line K has passed the signal *d* and is about to get the safety signal at *c*. This of course illustrates in the simplest way not only the interlocking arrangement of the four signal-crosses, but the relation of the circuit-closing studs of each commutator to the signal-cross to which it belongs. It is desired to set the signal *c* a quarter-turn to the right, and hence to "safety." This can be done because circuit is complete from the magnet 8, which controls the locking-dog 9 of the wheel 10 and is energized through the circuit made by the wire 11. This circuit is possible because the four commutators of the signals *c d e f* each have a pin closing contact between the springs 12 13 14 15 and so making circuit between the positive and negative feeders X—that is to say, the circuit from positive conductor X proceeds through the

coil of magnet 8 and then through the closed-contact springs 12, 13, 14 and 15 to the negative conductor X. Now assume the signal-cross *c* to be turned a quarter of a turn to the right. The commutator of that cross will then also be rotated so as to close circuit at 40 and break it at 12. Then circuit will be made through the magnet 16 of the signal-cross *d*. This circuit will proceed as follows: from positive conductor X to magnet 16, to closed-contact springs 40, closed-contact springs 19, to negative conductor X. Magnet 16 will then lift the locking-dog 17 out of the wheel 18, thus making it possible to set the signal *d* a quarter of a turn ahead and so to "danger." The rotation of signal *d* also rotates its commutator, which breaks contact at 13 and 19 and establishes it at 20. Circuit then proceeds from positive conductor X to magnet 21, to closed-contact springs 20, to closed-contact springs 23, to negative conductor X. Therefore the magnet 21 belonging to signal *e* is energized to lift the locking-dog 22, and therefore the signal *c* can be turned one quarter turn ahead and also to "danger." Because the signal *c* has been turned its commutator then breaks circuit at 14 and 23 and closes circuit at 24. The circuit thus established proceeds from positive conductor X to magnet 25, to closed-contact springs 24, to closed-contact springs 24x, to negative conductor X. The magnet 25 thus energized raises the dog 26, so permitting the signal *f* to be turned ahead one quarter-turn, which leaves that signal at "danger" and also in the position which has been defined as the normal position of all the signals on the line when no train is on it.

Turning now to Fig. 5, this shows not only the relation of simply four signals, as does Fig. 4, but also the relation of these four signals to the other signals, and from this diagram the relation of any one of these signals to the interlocking mechanism may be readily traced. It will thus be clearly seen that the interlocking mechanism here illustrated is fully competent to perform the object hitherto set out and to do so in a very simple and efficient manner.

Special attention is called to the fact that when the line is in its normal condition—that is, unoccupied by trains—there is no expenditure of current, because all of the circuit-closing springs which establish circuit between the positive and negative feeders are open, and this state of affairs prevails at every signal station where the signal-cross is in the position of *g h i j*, or, as hitherto explained, the "normal" position. It also follows that there is no expenditure of current except through the one signal immediately in advance of the train and the three signals immediately in rear of it. Therefore the minimum amount of current is utilized to accomplish the desired result, or, to put it another way, every connection of the line is dead except those which are directly preceding the signal preceding the train and the three signals guarding its rear.

There is of course modification in the arrangement of the interlocking mechanism at the beginning of the line, illustrated in Fig. 6. Here the signal-crosses *g h i j* are all set in normal position. As-

sume a train to come in the direction of the arrow up to signal *j*. That signal can then be turned one quarter-turn to the right to exhibit the safety-arm, because circuit is made through its magnet 27 and the springs 28; but when signal *j* is turned one quarter-turn ahead its commutator breaks circuit at 28 and establishes it at 29. Therefore circuit is made through the magnet 30 of the signal-cross *i*, and that unlocks that signal-cross, so that it in turn can be set a quarter-turn ahead to give the oncoming train the safety-signal. The effect of that turn is to break circuit at 31 and establish it at 32, while also permitting the cross *j* to be turned forward another quarter-turn, thus closing circuit at 33. Circuit is then made through magnet 31 of signal *h*, so that that signal may be set ahead a quarter-turn. The result is to break circuit at 37 and close circuit at 34, while signals *i j* may each now again be set forward a quarter-turn, closing

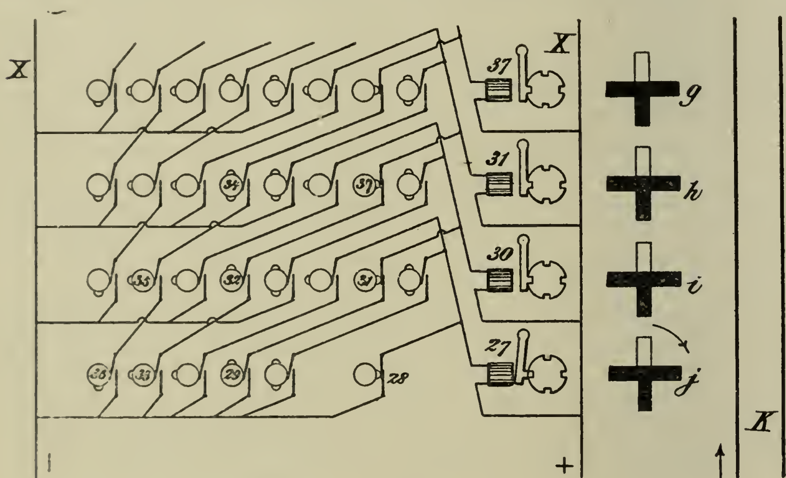


Fig. 6.

circuit at 35 and 36, thus energizing magnet 37 to release its lock and so allow signal *g* to be turned ahead a quarter-turn. The net result is that before the second signal—namely, signal *i*—can be put to "safety" signal *j* must be put to "danger," before the third signal *h* can be put to "safety" both signals *i j* must be at "danger," and before the fourth signal *g* can be set to "safety" all three preceding signals *h i j* must be set at "danger." This is the condition which, as already explained, prevails so long as the train is on the line.

The operation of this system has been elaborated by diagrams showing each successive "move" or position of train or trains in every possible combination either "normal" or "irregular". These diagrams show the impossibility of any human error resulting in an accident. They are too voluminous to reproduce here.

This system can readily be made automatic and can be applied to a steam road as well as an electric railway.

2. COMBINED TRAIN ARRESTING AND SIGNALING MECHANISM.

This invention relates to electric railways wherein there is an electric-motor vehicle and a line conductor wherefrom the motor of said vehicle derives its actuating-current.

The invention consists, first, in the improvement in the art of governing the movement of an electric-motor vehicle taking its actuating-current from a line conductor, as aforesaid, which consists in controlling the maintenance of electrical circuit between said motor and said conductor at a point on said conductor from a station distant from said point; also, in the combination of such a line conductor and electric-motor vehicle, as aforesaid, with a signal in proximity to said conductor, of means for actuating said signal and also for simultaneously controlling the closing and breaking of electrical circuit between said motor-vehicle and said conductor at a point distant from said signal; also, in the construction and arrangement of the circuit-breaking devices, of the combined circuit-breaking devices and signal, of the circuit-breaking devices in combination with mechanism for applying the brakes to the vehicle, together with the other combinations and instrumentalities hereinafter more particularly pointed out in the claims.

In the accompanying drawings, Fig. 7 is a side elevation showing a signal apparatus in combination with means for breaking circuit between the third rail of the railway and the motor on the vehicle. Fig. 8 is an end elevation of the third rail and its support and of a car on the main line, showing the contact-arm between car and third rail and the operation of said contact-arm to actuate the brakes.

Similar letters of reference indicate like parts. A represents the main railway-line. B is a third rail elevated upon a support, as C, and extending parallel to the track A. The third rail B is, as usual, insulated from the ground. D represents a car, and E the driving electric motor thereof. F is an arm pivoted at G in the car and provided with a retracting-spring H, normally operating to press it in contact with the third rail B.

It will be understood, therefore, that under normal conditions, with the car traveling over the track, circuit proceeds from the third rail B, through the arm F, to the motor E, and so to the main track A and ground.

I is a signal-arm pivoted at the top of the post J and connected by a vertical rod K with one end of the bell-crank lever L. The other end of lever L is pivoted to the rod M, which extends below the third rail B. This rod M is pivoted to the lower ends of the pivot-levers N, the upper ends of which levers are all pivoted to a bar O, preferably having an upper inclined surface P.

Turning now to the contact-arm F, Fig. 8, this is connected by pivot-levers Q to the ordinary conductor's valve R of an air-brake system and so arranged that when said lever F is elevated into the position shown in dotted lines, Fig. 8, the said valve R will be

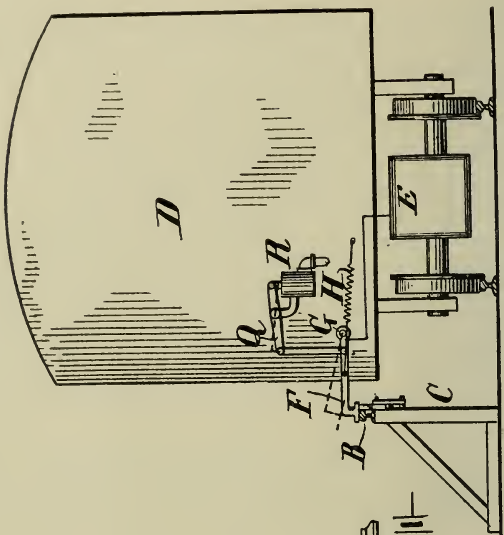


Fig. 8.

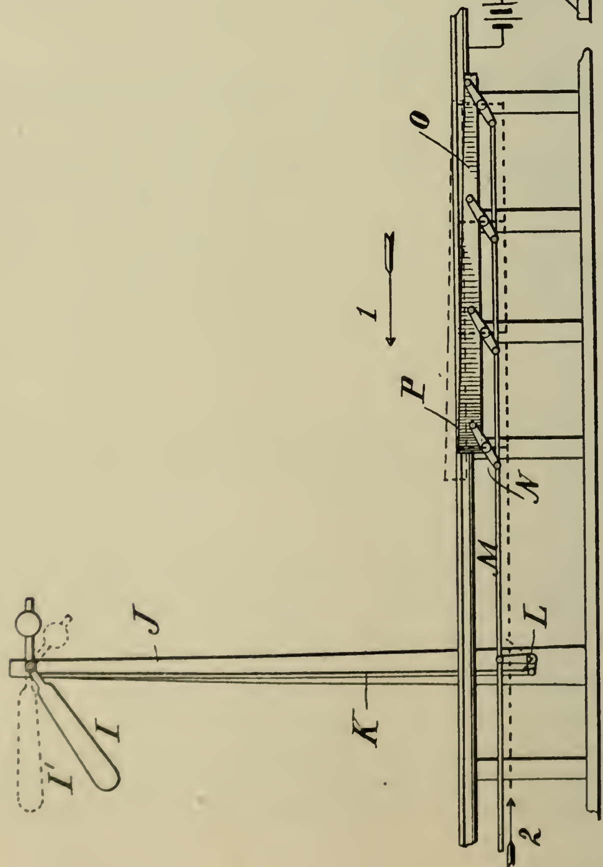


Fig. 7.

opened to operate the air-brakes on the vehicle or train in the usual manner.

The operation of the whole device is as follows: Assuming the vehicle or train to be moving in the direction of the arrow 1, Fig. 7, let rod K, by any suitable means, be moved upward so as to bring the signal-arm I into the position I′, dotted lines, this position being that indicating danger to the train approaching it. The elevation of the rod K then vibrates the bell-crank L, moving the rod M in the direction of the arrow 2, so turning the pivot-levers N and elevating the bar O, so that its inclined upper surface P rises above the level of the surface of the third rail, as indicated in dotted lines, Fig. 7. If then a vehicle provided with the arm F, as described, on coming up to the signal I and finding that signal set at "danger" I′ does not stop, its arms F will run up on the elevated bar O and so be brought into the position shown in dotted lines in Fig. 8, thus breaking contact between the end of arm F and the third rail B and so breaking circuit through the motor E. The car would therefore stop on account of the cutting off of the source of energy; but in addition to this, as already explained, the arm F in rising operates the conductor's valve R and so causes simultaneously the application of the brakes to the vehicle.

It is to be understood that there is no limit to any particular form of visual signal nor to any special means actuated by the contact-lever F for the purpose of insuring the application of the brakes.

It is old to place stops beside the track of a steam railway to cause a closing or breaking of an electrical circuit on the locomotive through which a bell or whistle or some other alarm mechanism is actuated, also it is old to place beside a track a movable projection which when struck by the vehicle and brought back to normal position actuates a switch or signal or analogous devices.

It is also old in electrical railways to provide a fixed stop in proximity to a track or conductor whereby a shoe or trolley is temporarily held out of contact with the conductor at certain definite places, such as crossings or other points where it is desired that there never shall be any electrical circuit between the motor and the line conductor, or, in other words, where it is always requisite that the current shall be broken.

It is readily seen that to apply this to a steam railroad it needs but slight modification. A third rail is unneccessary, for the breaking of the current path is not required, there being none. The inclined "safety" bar can be located at a "home" signal tower which may be raised by setting the signal to danger and lowered when set at safety. A shoe attached to the locomotive will be operated by the bar as already described and a "graduated" device can automatically apply the air brakes bringing the train to an easy stop, such stops being entirely beyond the control of the engineman.

The importance of some means of automatically stopping a train which disobeys orders is clearly indicated by tables No. 1, 2 and 3.

TABLE No. 1.

Approximate total number of casualties to passengers and employees in train accidents, 1888 to 1899 inclusive:

Years.	Negligence in Operation.		All Other Causes.		Grand Total, All Causes.
	Total.	Per Ct.	Total.	Per Ct.	
1888	1,270	47	1,442	53	2,712
1889	1,121	53	1,046	47	2,167
1890	1,935	55	1,549	45	3,484
1891	1,856	54	1,501	46	3,357
1892	1,681	58	1,255	42	2,936
1893	1,671	55	1,284	45	2,955
1894	927	56	666	44	1,593
1895	967	53	813	47	1,780
1896	902	54	763	46	1,665
1897	909	53	788	47	1,697
1898	1,161	58	850	42	2,011
1899	1,497	60	1,001	40	2,498
Average (12 years)		55		45	

TABLE No. 2.

Approximate Total Number of Train Accidents, 1873 to 1899 inclusive.

Years.	Grand Total, All Causes.	All Collisions,		All Other Causes.	
		Total.	Per Ct.	Total.	Per Ct.
1873—77	1055	295	30	760	70
1878—82	1100	417	38	683	62
1883—87	1347	548	48	799	52
1888—92	2083	959	46	1124	54
1893	2307	996	43	1311	57
1894	1560	613	39	947	61
1895	1487	602	40	885	60
1896	1357	514	37	843	63
1897	1658	731	44	927	56
1898	2228	1021	45	1207	55
1899	2431	1141	46	1290	54
Average, 27 years.			41		59

TABLE NO. 3.

Approximate Total Number of Collisions of Trains, 1894 to 1899, inclusive.

Years.	Grand Total. All Causes.	Failure to Give or Observe Signals.		Error in Giving or Understanding Orders.		All Other Causes.	
		Total.	Per ct.	Total.	Per ct.	Total.	Per ct.
1894	613	54	8	31	5	528	87
1895	602	64	10	35	6	503	84
1896	514	33	6	48	9	433	85
1897	731	58	8	33	4	640	88
1898	1,012	115	11	47	5	850	84
1899	1,141	98	9	70	6	973	85
Average (6 years)			9		6		85

We see from these that 55 per cent of all railroad casualities (killed and injured) to passengers and employes are due to negligence in operation (from table No. 1). If we assume that these casualties are proportionately distributed (this probably charges too little to collision account) we have 22.5 per cent of all casualties due to collisions of all kinds (from table No. 2). Under the same assumption we have 3.4 per cent of all casualties due to failure to give or observe signals and error in giving or understanding orders (from table No. 3). While we cannot from statistics obtain the number of accidents or casualties due to failure to observe signals it is safe to say that somewhere between 3 per cent and 10 per cent of all casualties to passengers and employes are due to this one cause.

An application of the suggested device of shoe, "detector" bar and air brake would prevent many of these casualties.

XC.

PRESERVATIVE TREATMENT OF TIMBER.

By O. Chanute, M. W. S. E.

Read March 21, 1900.

It is now nearly twenty years since the writer was appointed to serve upon a committee of the American Society of Civil Engineers, to report upon the "Preservation of Timber." At that time the statistics concerning our forest supplies, gathered for the census of 1880, had impressed timber consumers and engineers very forcibly, and perhaps unduly. These statistics seemed to indicate that in our northern states east of the Rocky mountains the principal supplies of first growth white pine would become exhausted in about 11 years; that the standing spruce and the hemlock would mostly be cut down in about 25 years, and that white oak, walnut, ash and other hard woods had more than doubled in price during the preceding 25 years.

Moved by the apprehension of a timber famine, steps were then taken by various parties to diminish the consumption and the waste of timber, in order to ward off the impending increase in prices. The United States Department of Agriculture organized a division of Forestry, which has done very valuable work; builders substituted metal for wood where economically practicable in structures, and engineers turned to metallic bridges and to investigations of the best preservative processes for lengthening the life of wood exposed to the weather.

Singularly enough, the price of many varieties of manufactured timber did not advance materially. Railroad ties, for instance, were actually cheaper in 1890 than in 1880 in some sections of the country, probably in consequence of sharp competition between owners of timber lands who desired to realize upon their holdings; so that timber users becoming reassured, concluded that the proximate exhaustion of a material of construction which was constantly being fed by natural growth, must have been greatly exaggerated by those persons who thought it their duty to cry "Wolf!" and but few consumers resorted to preservative processes.

This quietude was rudely dispelled upon the revival of business in *1899*. The price of lumber, timber and ties advanced some 20 to 70 per cent in three months, and now seems firmly held. The increase came at a bound, as is not unusual with commercial prices

when the causes have gradually been accumulating. How much of the recent advance is legitimate, and how much prices may again recede will be determined by the future, but there is now very good reason for apprehending a growing scarcity of the more durable woods, and it seems a fitting time for the Western Society of Engineers to take up again one branch of the subject, and to enquire into the efficacy and economy of the preservative treatment of ties, which latter consume vast quantities of timber.

The report to the American Society of Civil Engineers was presented and accepted June 25, 1885. It is still so accessible that no reference need be made thereto further than to say that after spending five years in gathering data, the committee reported upon the results of 147 American experiments, classified as follows:

Experience in Kyanizing (corrosive sublimate)	16
Experience in Burnettizing (chloride of zinc)	30
Experience in Creosoting (dead oil of coal tar)	39
Experience in Boucherie (sulphate of copper)	18
Experience in miscellaneous processes and chemicals	44
	147

Those members who desire to be informed concerning the peculiarities of the various processes will find them set forth in that report, also in a very valuable paper upon "The Antiseptic Treatment of Timber," presented to the Institution of Civil Engineers of Great Britain by Mr. S. B. Boulton, May 6, 1884, and also in a paper on "The Artificial Preservation of Railroad Ties by the Use of Zinc Chloride," presented to the American Society of Civil Engineers, May 17, 1899, by Mr. W. W. Curtis, to which reference will hereafter be made.

Now, the great timber users are the railroads, and their principal consumption is for cross ties; it being generally estimated that the railways now lay down about 100,000,000 ties annually, this alone requiring the yearly stripping or culling of over 1,000,000 acres of our best forests, upon the assumption that an average of 100 ties are taken from each acre. Appreciating these facts some few sagacious railroads began tentatively the treatment of perishable and cheap woods for ties in 1885 and 1886. They were the pioneers in recent years, for former experimental plants had been given up, and that these leaders have already accomplished good economic results for themselves is evidenced by the fact that all save one (whose works were burned) are continuing the process now. These roads were as follows:

The Atchison, Topeka & Santa Fe Railroad was the first to take the lead in 1885. It built a tie preserving plant at Las Vegas, New Mexico, which has since been enlarged by 50 per cent, and in 1898 it built a similar plant at Bellemont, Arizona. Both employ the "zinc-tannin" process.

The Union Pacific Railway built a tie preserving plant at Laramie, Wyoming, in 1886. After working one year, with the zinc-tannin process, the works were temporarily shut down to save current expenses. They were burned shortly afterwards and have not been rebuilt.

In 1886 the Chicago, Rock Island & Pacific Railway contracted with Card & Chanute, (since organized as the Chicago Tie Preserving Company,) to erect works at Chicago and to treat 100,000 to 200,000 ties annually for five years. At the end of that time the contract was extended for three years, and the quantity increased to 300,000 ties a year. Upon its expiration this contract was renewed for ten years more for an output of 400,000 to 500,000 annually, to be treated by the zinc-tannin process. This last plant brought the writer into the practical operation of such works rather unexpectedly to himself. He had been engaged in the designing and building of the plants at Las Vegas and at Laramie, and when the Chicago plant was decided upon he went into a partnership with Mr. J. P. Card, who had been operating a plant at St. Louis for some years. Mr. Card ran the Chicago works for 9 years, and died in the latter part of 1894, since which time the writer, who had previously acted chiefly in an advisory capacity, has taken active charge of the work. In 1899 he built and is now operating a movable plant at Mt. Vernon, Illinois, to treat ties for the Chicago & Eastern Illinois Railroad.

In 1891 the Southern Pacific Company, after operating a leased plant for some three years, built tie treating works of its own at Houston, Texas, and obtained such promising results that in 1894 it built an additional plant, which was made movable, to be used alternately in California and Oregon. This last plant is to be operated in Texas or New Mexico this year, to take advantage of cheaper prices for ties. This road employs the original burnettizing process, injecting chloride of zinc alone, and as most of the ties which it has treated at both its plants are laid in the more arid regions of the country, it has thus far experienced but little difficulty from the washing out of the zinc; a difficulty which led to the abandonment of the process in England some 40 years ago, in France some years later, and in Germany in 1897.

In 1899 the Chicago, Burlington & Quincy Railroad built a tie treating plant at Edgemont, South Dakota, which has only recently begun operation with the burnettizing process.

In addition to the above there are private works at Somerville, Texas, which operate the zinc-tannin process for ties, and at Beaumont, Texas, which treat either with zinc or with creosote, as required by the customers.

Creosoting is chiefly applied to timber exposed to marine worms. It is much the best process, but is too expensive to apply to ties. There are works for creosoting at Houston, Texas, at Pascagoula, La., at Norfolk, Va., at Indianapolis, Ind., at Long Island City,

N. Y., at Perth Amboy, N. J., at San Francisco, Cal., and at Seattle, Wash., which work chiefly on piles and timber.

As to ties, the results of the treatment have been fairly satisfactory. They are stated in detail in the paper of Mr. W. W. Curtis already alluded to, and the following are his conclusions:

SUMMARY AND DISCUSSION OF RECENT AMERICAN EXPERIENCE.

"From the preceding, the experience of American roads with treated ties may be concluded to be generally favorable. The Atchison, Topeka and Santa Fe Railroad officials, after 12 years' trial on a large scale, believe they are getting from 11 to 12 years' service from mountain pine, having a natural life of about 4 years; while from natural white oak they get but 6 years in heavy main line service; and from cedar 10 years under light service.

The Union Pacific Railroad reports about 9 years for mountain pine and spruce. The Chicago, Rock Island and Pacific Railroad report of the count of ties now in place, indicates a life of at least 8¾ years. The unimpeached counts of removals prior to 1894 show that in that year 84.7 per cent. of the ties laid 7 years previously was still in track. The record of the four sections just west of the Missouri River, as here figured, indicates a life of 11 years. The experience of the Pittsburg, Fort Wayne and Chicago Railroad with hemlock and tamarack ties, only 1 per cent. having been removed after 7 years; and of the Duluth and Iron Range Railroad, with white and Norway pine and tamarack which, after 7½ years' service and after having been taken up and relaid once, were still in nearly perfect condition; furnish conclusive evidence that the treatment is efficacious, and presumptive evidence that a life of 11 or 12 years may be expected. The discovery of about the same number of treated ties in the tracks of the Rock Island and Peoria Railroad, as were laid in 1891—at which time the last were laid—demonstrates how entirely mistaken were the officers of that road as to the life to be secured from such ties, even under the unfavorable conditions existing as to drainage and ballast.

The Southern Pacific Railroad, operating on the most perishable material, with a life of only 3 years at the best, had 93 per cent. of the ties treated and laid in 1889 still in the track after 8 years. The record for the ties treated during the 2 previous years was not as good, for known reasons; however, those laid during 1887 gave 10 years' service, and of the 1888 ties, 63 per cent. was still in use 9 years later."

The writer acknowledges that the average life in the track of ties treated at his own works prior to 1895 has not been satisfactory to himself. He expected these ties to last 12 to 15 years, and they have averaged but 9 to 11 years. In 1896, after a great many experiments, he modified the mode of treatment by using three solutions instead of two, and he now injects 2½ times as much chloride of zinc as was done in 1886, so that he anticipates that his original expectations will be realized. He has found, however, a great many anomalies in the injection of various woods. Some of the ties take two or three times as much solution as others; various kinds of wood behave differently; ties cut in summer average far less absorption than those winter cut; modifications in the period of steaming, in the time and amount of vacuum, as well as in the strength of the solution and the duration of the pressure, produce different results, some of which were puzzling; so that after 14 years of experience, the writer felt the need of going to Europe, where the preservation of wood has been carried on since 1835, in order to study "the state of the art,"

and to avail himself of the best methods of carrying on a work which did not prove to be as simple as was at first imagined.

The countries visited were England, France and Germany, these being the regions where wood preserving is done upon the largest scale,* and the following account of the information obtained will be confined to the preservation of cross ties, as this is the principal application of processes abroad.

The Europeans are obtaining much more service out of their wooden ties than we do in this country. In England the average life is at least 15 years under very intense traffic. For instance, the London & Northwestern Railway reports an average service of 16 to 20 years for its sleepers, all of which are creosoted at a cost of about 25 cents each. The London, Tilbury & Southend Railway says that its sleepers last 25 to 30 years, but this is a road with very light traffic. Other lines report the life at 12 to 15 years, one road alone, the Southeastern, reporting the service at 8 to 9 years, and the cause of failure to be "wear." All ties laid in England, or practically all, are creosoted with varying quantities of tar-oil, but generally with 28 to 30 pounds per tie. The sleepers are of imported Baltic red-wood, procured in Russia, Sweden and Norway, are generally 8 feet 11 inches long, 5 inches thick and 10 inches face, and cost from 90 cents to $1.12 apiece delivered at the dock, so that it is good economy to treat them with creosote to lengthen their life.

In France, speaking generally, still better work is done than in England, and better results are obtained. Formerly chloride of zinc and sulphate-of copper were injected, but now practically all the ties are creosoted (except by one road) and they last from 15 to 20 years. One road, the "Ligne de l'Est," obtains 25 to 30 years service out of beech ties, and there is no question as to the fact, for accurate records for 27 years prove it, but then this road injects 60 pounds of tar-oil per tie, after long seasoning and further drying in ovens, at a total cost of 64 cents each. Other roads inject lesser quantities and obtain inferior results. The increased life of the wood seems to be nearly in direct ratio to the amounts of creosote injected. The French ties are of oak, beech and pine, about three-quarters of them being produced in the country, and about one-quarter imported. The average renewal upon the French railways is now about 4½ per cent annually of all the ties in the tracks, so that the yearly depreciation in the United States is about twice and a half as much as in France. In the latter country one railway system, that owned by the State itself, employs the "zinc-creosote" process, which will be further mentioned when giving the data for Germany; all the other roads have practically gone over to creosoting, with some modifications as to the mode of injection.

In Germany three processes have been in vogue until recently. These consisted, first, in straight burnettizing, or the injection of

*Wood preserving is also carried on in Austria, Belgium, Holland, Denmark, Russia, Switzerland, Spain and Portugal.

chloride of zinc alone, such as is now practiced at some of the works in the United States which have been herein mentioned; second, in the "zinc-creosote" process in which both substances are simultaneously injected in an emulsion; and, third, in straight creosoting in which tar-oil alone is injected by one of several methods. In 1897 straight burnettizing was abandoned, it having been abundantly recognized that the chloride of zinc leaked out of the wood in time, and at present only the other two processes remain in practical application upon an extended scale. There are other methods still lingering of very limited application, and there are some new processes now coming forward which will be noticed further on.

The reason why burnettizing continued so much longer in Germany than in England or in France appears to be mainly climatic. Not only is the rainfall less in Germany, but its character is different, consisting, as the writer was informed, mainly of long drizzling rains which do not wash the ground and the ties like the heavy downpours in the other countries, which are so often followed by fierce evaporating suns. Be this as it may, the service hitherto obtained from burnettized ties in Germany has been from 9 to 12 years in the track; the timber injected has chiefly been pine and beech, and the cost of injection for first class ties, 8 feet 10 inches long, 10.2 inches wide and 6.3 inches thick, has been 15.6 cents each for pine and 18.8 cents for beech, which latter wood absorbs more solution. These woods are obtained locally, as the State owns some 31 per cent of the forest area of Germany, makes this a source of profit, and discourages importation.

The price paid for the injection with "zinc-creosote" of first class ties is 19.2 cents for pine, 20.4 cents for beech, and 15.6 cents each for oak, inasmuch as this last wood is very refractory and absorbs much less of the solution. The service obtained has been from 12 to 18 years in the track, but the most convincing evidence of the value of the process consists in the guarantee which the contractor, Mr. Julius Rutgers, (who first introduced this method,) has given in some cases. He first excludes 5 per cent of all the ties treated, as damaged by hidden defects and rotten spots which cannot be detected in inspection, and guarantees that of the remainder 95 per cent shall still be fit for service in 10 years, 80 per cent in 11 years, and 70 per cent in 12 years. If less than the above remain, and are proved to have been properly taken out for decay, he makes the deficit good by refunding the price paid for treatment or treating another tie gratis, at his option. In point of fact, inasmuch as a premium of 2.4 cents a tie is charged for this guarantee, the Prussian State Railways prefer to pay the regular price above mentioned for treatment, and to protect themselves by the issue of elaborate specifications which have been revised several times, making them more and more stringent, and by placing inspectors at the works.

In Germany, as elsewhere, straight creosoting gives the best results, but it is expensive. The price paid for the impregnation of

first class ties is 53.76 cents each for pine, 56.64 cents for beech and 26.88 cents for oak, the later being in consequence of the smaller absorption, if the creosoting is done after drying in special ovens. The price is 56.64 cents each for pine, 59.28 cents for beech, and 28.80 cents for oak, if boiled and impregnated in heated tar oil. The service obtained is 20 to 23 years for pine, 30 to 34 years for beech, and 24 to 28 years for oak; these figures as to life being taken from the report of the Union of German Railways for 1896, published in organ of railroad progress, Weisbaden, 1897. The results must seem astonishing to our American railroad managers, but then, very great care is taken of the ties after they get into the track, the mode of fastening to the rail is superior to our own, and all the inspections are rigid.

Nothing impressed the writer more forcibly than the extreme care, and the particular precautions enforced, in Europe in order to do the best kind of work. The ties are minutely inspected when first received, and the German specification would appall an American tie contractor; the amount of wayne is elaborately specified, and a single rotten spot, or red heart, in beech, condemns a stick. If there are incipient cracks at the ends, sharpened straps of heavy tapering hoop iron, bent into the shape of an S, are driven in, or a hole is bored with an auger, and an iron bolt is inserted and screwed up against washers. The ties are then seasoned from 6 to 12 months before they are impregnated. They are cribbed up in isolated square piles of about 100 ties, with some 4 inches air spaces between the sticks, so that they may dry thoroughly in the yards adjacent to the treating works. Some of these yards can contain 600,000 ties, and the writer saw one in which 250,000 ties were piled up for this year's treatment. The piles are examined from time to time to determine when the wood reaches the best condition; if more cracks are developed, more S-straps are driven in. This careful seasoning, the result of long experience, constitutes one of the principal differences from American practice, in which the ties are treated within three or four months from the time of their cutting, and it accounts in a great degree for the inferior results which we have hitherto obtained. After the ties are treated they are again piled up and allowed to dry before being put into the track, although this precaution is less strenuously insisted upon and emergencies are met by laying freshly treated ties.

It is the work of impregnation which is subjected to the greatest care. It is carried on by experts, and to elaborate specifications. As most applicable to the United States the specifications of 1895 of the Royal Prussian State Railways are herewith given in an appendix. Those reading them will note the process: "A. Impregnation with chloride of zinc only" was given up in 1897. While carrying on the work inspectors are in attendance to test the strength and purity of the substances injected, and for this purpose a chemical laboratory is attached to each treating plant; the ties are weighed

by buggy loads before and after treatment, and the amounts absorbed are thus checked. If a buggy load proves deficient it is treated over again. To ensure uniform work, automatic gauges with clock-work attachment register the amounts of vacuum and pressure obtained in the treating cylinder, as well as their duration, and a record diagram is taken and preserved of each treatment. Thus is obtained a uniform absorption of the chemicals in the prescribed quantities and thus are produced the satisfactory results in service which have already been mentioned.

Much of the credit for the careful work done in Germany is due to Mr. Julius Rutgers, a contractor who has been in the business for just 50 years. He is a man 70 years of age, and now controls some 20 plants which do most of the tie treating for Germany. The Royal Prussian State Railways, which comprise practically all in Prussia, have four tie treating plants of their own, but several of the state officials told the writer that Mr. Rutgers was so thoroughly equipped and through his long experience enabled to do so much better work than the state itself, that the latter preferred to contract with him rather than to enlarge the present railway plants. He is in no wise protected by patents, but simply by his known skill and honest work.

Further care is exercised in laying the ties in the track, and the mode of fastening to the rail is decidedly superior to our own. In Europe ties are generally adzed and bored for spikes by machinery before being treated. The adzing provides a smooth seat for the chair, tie plate or rail, which latter is generally laid on a "cant," and the boring not only obviates the crushing of the fibres of the wood by a spike, were such a primitive mode of fastening still generally used, but it also assures thorough chemical treatment at this dangerous spot. In point of fact it may be said that the spike has now been abandoned in the three countries which have been above named. In England the standard is the "bull-head" rail, a rail with two heads, and it is laid in cast iron chairs which are fastened to the tie by round iron dowel pins and wooden tree-nails, driven into bored holes. In France and in Germany the foot rail is generally used, together with tie plates, and the latter are fastened to the tie by lag screws of various designs. In some cases spikes are used on the outside, and the spike is used on both sides in side tracks, but the lag screw, which the French call "tirefond" is considered the standard. In France holes for these are bored by machinery, but the German now generally bore for these by hand when laying in the track. They admit that it would be cheaper and better to bore before treatment, so as to impregnate thoroughly around the hole, but they are now experimenting with so many patterns of tie plates and rails that they cannot tell before treatment to which pattern the tie is to be fitted. The French have been using not only iron tie plates, but also some made of felt, and claim that the latter last 6 to 10 years, at a cost of 1.6 cents each, but these are now being superseded by creo-

soted poplar tie plates, cut from the lower gnarly portion of the tree, to about the thickness of a shingle, which are said to be more economical than either iron or felt tie plates. The argument made is that the iron tie plate wears both the rail and the tie, while the poplar tie plate takes all the wear to itself, and, as it costs but about .8 cent, proves most economical.

But the great, the radical, improvement in tie fastening consists in the discarding of the barbaric spike, which when driven, crushes the wood into a spongy mass, collects moisture to rot the tie, gets loose and allows the rail to flap up and down so as to cut the tie at each stroke. The sooner we set about to supersede this with some form of lag screw appropriate to our rails, the better it will be for track economy. In Europe the lag screw is conceded to be as much of an improvement upon the spike, as the fish plate proved to be upon the old fashioned chair.

It will be realized from the above that great care is exercised in the preservative treatment of timber in Europe. The timber is closely inspected, it is thoroughly seasoned, it is impregnated upon scientific principles, and it is laid in well drained ballast with track fastenings superior to our own. It is therefore not surprising that much better results as to service are obtained than in this country.

The question which now occurs is how much of the European practice can profitably be adopted in the United States? It has been abundantly proved by over fifty years of experience that creosoting is the best preservative of timber, but also that it is the most expensive, and it is now yearly growing more expensive, as the price of tar-oil is advancing year by year with the recognition of its merits. In consequence of the high price paid for stumpage the Europeans start with a much more expensive tie than we do. In England, for instance, a pine tie untreated costs 90 cents to $1.12, in France it costs about $1.00 and in Germany from 82 to 90 cents; hence more money can be spent upon it profitably to prolong its service. It would cost, at the present price of creosote, about 45 cents each to impregnate ties according to the English practice, and about 85 cents to inject it with the quantity prescribed by the "Chemin de fer de l'Est" in France, where the process involves the baking of the tie for 72 hours in a drying oven before injection. It is hardly to be expected that our railroad managers will feel justified in incurring this expense to preserve a tie which costs but 20 to 40 cents in the first place. We must therefore resort to cheaper processes, recognizing them as inferior, and yet more appropriate to the cheaper timber which we are still so fortunate as to possess.

Now what shall that process be? Opportunely for us European experience has made the choice of the substance to be used more limited than it was a few years ago. Sulphate of copper and bichloride of mercury, although excellent antiseptics, have proved to be, on the whole, less available for timber preserving than chloride of zinc, and although the latter when injected alone has now been

abandoned in all the three countries mentioned, some modifications of burnettizing may profitably be employed in this country. Indeed, in the more arid regions of the United States chloride of zinc alone will probably give satisfactory results, but there must be plenty of it injected, certainly more than is the practice at present at some of the works; for it has been well established that it leaches out during the alternate soaking and drying which the ties undergo.

It will be observed in the German specifications hereto appended, that a pine tie, for instance, which contains 3.96 cubic feet, is required to absorb 35 kilograms, or 77 pounds of the solution; as this solution is specified to be at 3.5 degrees Beaume, which contains 2.63 per cent of dry zinc-chloride, it follows that the amount of the latter substance carried in by the aqueous solution is 1.92 pounds per tie, or at the rate of .49 pounds to the cubic foot of wood. This corresponds to the present practice of the writer, who has been injecting, as closely as possible, .50 pound to the cubic foot for the last three or four years, with what practical results we shall not know to an absolute certainty for 8 or 10 years to come. As the ties reach him much worse seasoned than is the practice in Germany, and as he cannot inject as many pounds of solution, he is making the latter 5 degrees Beaume strong, containing 3.9 per cent of zinc chloride, and he thus puts in as much dry chloride as the Germans. This refers to the first solution employed, which is followed by two others. The second consists of gelatine or glue, and the third of tannin, the peculiarity being that these two latter substances, which are both soluble, form, when brought into contact with each other, an insoluble compound, an artificial leather in fact, the pellicles of which lodge in the sap cells of the wood and obstruct the ingress and egress of moisture, but not of vapor. The wood being already nearly filled by the first solution, the last two do not penetrate very far, say about three-quarters of an inch, but this is sufficient to act as a rough plug, and it has been proved to retard materially the leaching out of the zinc. It has moreover been found important to allow the ties so treated to dry somewhat before being put into the track, in order to allow the pellicles of artificial leather to harden. It has also been found that the ties last better in some soils than in others; limestone ballast and coal mine refuse, or culm, being seemingly the most injurious. For regions of considerable rainfall, the writer entertains no doubt that this "zinc-tannin" process is superior to straight burnettizing when equal amounts are injected.

The German method of retarding the leaching out of the chloride of zinc (for they say that it washes out even then), has been to mix therewith a certain quantity of tar-oil, which by lining the sap cells of the wood and hardening therein shall prevent the intrusion and the exit of moisture. The measure of success which they have accomplished has already been given, and this success seemed, by report, to be so much greater than that with ties treated by the "zinc-tannin" process, from 1886 to 1896, at the works of the writer,

that he devoted great scrutiny while abroad to the "zinc creosote" process, with a view to adopting it should it clearly be superior. As a result of that scrutiny he believes it to be very good, but he is not now certain that the results will warrant the increased expense, which will be 3 or 4 cents a tie, inasmuch as a part of the increased service in Germany, as compared with the United States, is attributable to other causes, such as the more thorough seasoning of the wood, the better track fastenings, the character of the rainfalls, etc. It is a significant fact that the Germans report a life for untreated white oak of 10 to 16 years, with an average of 13.6 years, while we can only obtain a life of 8 to 10 years for that wood in this country. Moreover, it will be noticed in the specifications appended, that while for straight creosoting only 10 per cent of tar-acids are required in the tar-oil, for the "zinc-creosote" process a peculiar quality of tar-oil, containing 20 to 25 per cent of tar-acids is required, which quality is not now produced in the United States. The introduction of this process therefore requires material changes in the distillation of coal tar in this country, or the importation of foreign tar-oils, which are just now very scarce and high.

Be this as it may, the writer deems it desirable that the "zinc-creosote" process shall be introduced in the United States, and it is his intention to do so, but it will require some time to investigate the best sources of supply, and to make chemical analysis of the products, and it will perhaps be necessary to erect a tar-oil refinery, as the process has to be carried on with great nicety, and some of the foreign plants are found to do much better work than others.

The question also occurs whether there are not other cheap processes which might be profitably introduced in this country. The writer learned of three new methods now being promoted in Europe. One is the "Hasselmann" process, which consists in boiling the wood in a solution of the sulphates of copper and iron, with alumina and "kainit," a salt mined at Stassfurt, Germany, consisting chiefly of sulphate of potassa and magnesia, and the chloride of magnesia. The process has been experimented with about three years in various parts of Germany, but of course the time is too short to be sure as to the results. Another process, now being experimented upon by a Berlin chemist, may be termed the "water-creosote" process. It consists in mixing intimately tar-oil with water in varying proportions; the rationale of which is that the tar-oil will be thereby much more uniformly distributed throughout the wood, and hence a less quantity will suffice. The writer saw a number of specimens prepared by this process in Berlin, and they seemed to be quite uniformly impregnated. Still another process is being worked up in Russia, where some skilful chemists say that they have obtained an antiseptic element from the refinement of petroleum, and are studying its practical application to the preservation of timber. The weak point, however, about all new processes, is that they require the sanction of time before it is safe to adopt them otherwise than experi-

mentally. Chemists have so many times been disappointed by the results obtained with antiseptics or methods which they recommended that it is now recognized that a process should be tested 10 to 15 years in track before it is adopted fully. It seems to be well established that any soluble salt will wash out of the wood in time, and theoretically it would seem most desirable to replace the water used in making the solutions with an oily solvent to carry in the antiseptic and thereafter resist the intrusion of moisture. The writer has been seeking such a solvent for 15 years; he has made experiments himself and has had them made by chemists, without ever having been able to obtain a true solution of an antiseptic in an oily medium. He would have great faith in such a combination as a preservative of timber.

Whatever process is adopted, however simple it may seem, it will be found that care, skill and experience must be bestowed upon every detail of the work in order to ensure success. The Europeans as well as ourselves, made mistakes in the beginning; they erred sometimes in the choice of the process, in the quantities injected and in the methods of application. The wood preserving business has there drifted into the hands of a few experts, who make it a life business, and we may now profit from the knowledge which they have accumulated. Engineers should therefore study in detail the best methods of doing the work if they are to carry it on themselves, or of guarding the interests of their principals if it is to be done by contractors, for there will always be a temptation to be sparing in the injection of expensive chemicals. Chloride of zinc, for instance, costs more than sugar, and creosoting costs three times as much as burnettizing. There are now signs that the preservative treatment of timber is destined to be considerably extended in this country, and it is hoped that this paper will conduce to the promotion of good work and to economical success.

APPENDIX.

ROYAL PRUSSIAN STATE RAILROAD ADMINISTRATION.

DESCRIPTION OF THE VARIOUS IMPREGNATING PROCESSES AND SPECIFICATIONS CONCERNING THE COMPOSITION AND PROPORTIONS OF THE IMPREGNATING FLUIDS.

1895.

A. IMPREGNATION WITH CHLORIDE OF ZINC ONLY.

This process consists of three operations:

1. Steaming the timber.
2. Producing a vacuum and admitting the chloride of zinc solution.
3. The application of the pressure pump.

1. *Steaming the Timber.*

The timber being in the hermetically closed impregnating cylinder is first subjected to the action of steam. The time necessary for steaming depends

on the time of the year, and the condition of the wood. The object of this steaming is to put the timber in a condition for absorbing the greatest possible amount of the preserving fluid, to dissolve and to remove the mixture of sap, sand and dirt at the faces of the ties, and which is likely to cover the ends.

The admission of steam to the impregnating cylinder is to be so arranged that the gauge attached to the cylinder shall indicate a steam pressure of 1½ atmospheres (22 lbs.) at the end of not less than thirty (30) minutes after beginning the process. This steam pressure must be kept up for a further period of thirty (30) minutes.

For green timber the steam pressure of 1½ atmospheres must be kept up for sixty (60) minutes, as otherwise it probably would not absorb the amount of impregnating fluid specified in the contract.

In order to expel the air from the cylinder at the beginning of the steaming, a valve attached to the lower part of the cylinder must be opened until steam begins to escape; this valve must also be opened from time to time during the process of steaming, in order to draw off the water of condensation.

The above rules apply to oak and pine timbers.

As beech wood contains larger amounts of sap, which easily ferments, steaming must be continued at the above mentioned pressure for such time that the sap in the heart of the tie shall reach the boiling point. In treating beech wood, whether it be green or seasoned, steaming shall be continued for four (4) hours at the above mentioned pressure, including the thirty (30) minutes which are required to produce the pressure of 1½ atmospheres.

After steaming the wood for a sufficient length of time the steam is allowed to escape from the cylinder.

2. *Producing the Vacuum and Admitting the Chloride of Zinc Solution.*

After the steam is exhausted from the cylinder a vacuum of 60 cm. (23.6 inches) of mercury, as indicated on the gauge, is produced in the cylinder charged with timber, and this amount of rarefaction must be kept up for 10 minutes. Thereupon, without decreasing the vacuum, the process of filling the cylinder with the Chloride of Zinc solution, previously heated to at least 65 deg. celsius (149° F.) is begun.

3. *Applying the Pressure Pump.*

After filling the cylinder, the chloride of zinc solution is forced into the timber by means of a pump, the pressure being raised to at least 7 atmospheres (103 lbs. per sq. in.).

In order to saturate the timber as completely as possible, the pressure must be maintained for pine and beech wood for at least 30 minutes, and for oak 60 minutes. If necessary, the time must be extended until the specified amount of Chloride of Zinc solution has been absorbed. This process completes the impregnation, and the chloride of zinc solution is then drawn off.

Composition of the Chloride of Zinc Solution.

The solution of Chloride of Zinc used for impregnation must be as free as possible from impurities, particularly from uncombined acid. The solution must have a strength (density) of 3.5° Beaume = specific gravity of 1.0244 at a temperature of 15 deg. C. (59° F.). A solution of such strength contains 1.26 per cent of metallic zinc.

Guarantee as to the Amount of Chloride of Zinc Solution Absorbed.

It is guaranteed that the average amount of Chloride of Zinc solution absorbed in each cylinder charge will be:

a. For a pine tie 16 x 26 cm. and 2.7 m. long..............35 Kg.
For a beech tie of same dimensions...................36 Kg.
For an oak tie of same dimensions.....................11 Kg.

b. For a pine tie 16 x 26 cm. and 2.5 m. long..............32 Kg.
For a beech tie of same dimensions...................34 Kg.
For an oak tie of same dimensions.....................10 Kg.

c. For a pine tie 14 x 24 cm. and 2.5 m. long..............26 Kg.

For a beech tie of same dimensions.......................27 Kg.
For an oak tie of same dimensions...................... 8 Kg.

d. For timbers of various sizes per cubic metre:
For pine of various sizes per cubic metre............310 Kg.
For beech of various sizes per cubic metre............325 Kg.
For oak of various sizes per cubic metre..............100 Kg.

This guarantee is made subject to the proviso that the timber is sound, has been felled in winter and is seasoned, so that:

a cubic metre of pine does not weigh over................630 Kg.
a cubic metre of beech does not weigh over............725 Kg.
a cubic metre of oak does not weigh over..................800 Kg.

If the guaranteed absorption cannot be attained on account of insufficient seasoning or exceptional density of the timber, the Chloride of Zinc solution must be strengthened. For instance: If a cubic metre of pine absorbs but 200 Kg. instead of 310 Kg. of Chloride of Zinc solution, the density of the solution must be increased to 5.43 deg. Beaume, so that the solution used for impregnation, reduced to its contents of pure, dry chloride of zinc, shall be equivalent to the guaranteed absorption.

The samples used in testing the Chloride of Zinc solution must be taken from a tube communicating directly with the impregnating cylinder. In case a test shows that the solution requires strengthening by the addition of a more concentrated chloride of zinc solution, a second test shall be made after the strengthening, in order to make sure that a solution of the specified strength has actually been present in the impregnating cylinder for a period of 30 minutes.

In order to determine the amount of chloride of zinc solution absorbed in the process of impregnation as described, the timber is to be weighed twice on platform scales, first before being introduced into the cylinder and again immediately after treatment, while being taken out of the cylinder. The difference in weight shows the quantity of preserving fluid absorbed.

B. IMPREGNATION WITH CHLORIDE OF ZINC SOLUTION WITH AN ADMIXTURE OF TAR OIL CONTAINING CARBOLIC ACID, ACCORDING TO A PROCESS INVENTED AND INTRODUCED BY JULIUS RUTGERS.

The process consists of three operations:

1. Steaming the timber.
2. Producing a vacuum and admitting the preserving fluid.
3. The application of the pressure pump.

The impregnation is to be carried on by exactly the same process as prescribed for the chloride of zinc solution alone, in the preceding part A. of this specification. The same conditions will obtain concerning the composition of the chloride of zinc solution and guarantee for the absorption of the preserving fluid. While the chloride of zinc solution is being heated, an amount of 2 Kg. of tar oil shall be added to the solution for each tie of a length of 2.50 m. and over, or 20 Kg. tar oil for each cubic metre of timber.

The mixing of the tar oil with chloride of zinc solution shall be done by means of an efficient mechanical device, and a jet of steam and air.

Composition of the Tar Oil to be Used.

The tar oil must contain not more than one per cent of oils that boil below 125 deg. C. (257° F.).

The boiling point of the tar oil as a whole must lie between 150 deg. and 400 deg. celsius (302 and 752° F.) and not more than 25 per cent must become volatile below 235 deg. celsius (455° F.). At least 20 to 25 per cent of its constituents must be acids dissolving in caustic soda lye of 1.15 spec. grav. (oils of the creosote or carbolic acid type).

At 15 deg. celsius (59° F.) the tar oil must be completely fluid, and must be as free as possible from napthaline, so that when distilled in glass vessels, in groups of 50 degrees each (fractional distillation) it shall give off not more than 5 per cent of napthaline. The specific gravity of the tar oil at 15 deg. celsius (59° F.) must lie between 1.020 and 1.055.

C. IMPREGNATION WITH DEAD OIL OF TAR CONTAINING CARBOLIC ACID WITH THE USE OF A DRYING OVEN.

This process consists of three parts:

I. The drying of the timber in the drying oven.

II. The production of a partial vacuum and the admission of the dead oil of tar.

III. The application of the pressure pump.

I. Drying the timber in the drying oven.

The timber is placed in a properly constructed drying oven and there exposed to a temperature gradually rising to 110 deg. C (230° F). The drying is continued at least 8 hours or as much longer as may be necessary, until no more aqueous vapors escape and the wood is uniformly heated.

As soon as the drying is completed, the wood in its warm condition is at once introduced into the impregnating cylinder which is immediately hermetically closed.

II. Production of the partial vacuum and admission of the dead oil of tar.

A vacuum of at least 60 cm. (23.6 in.) of mercury is next produced in the tank and is maintained for ten minutes. The dead oil of tar is then admitted without diminishing the vacuum. The tar oil must previously be heated in the oil reservoir to at least 50 deg. C (122° F.) by means of steam pipes.

III. Applying the pressure pump.

After filling the impregnating cylinder the oil of tar is pressed into the timber by pumping and the pressure is raised to at least 7 atmospheres (103 lbs.) above the external pressure of the air.

This pressure must be maintained in the case of pine and beech wood for at least 30 minutes and for oak 60 minutes.

If necessary the time must be prolonged until the specified amount of tar oil has been absorbed.

This completes the process of impregnation and the oil is then drawn off.

Composition of the Oil of Tar to be Used.

The oil of tar must be made from mineral coal tar and must contain not over one per cent of oils that boil below 125 deg. C. (257° F.). The boiling point of the oil of tar as a whole must lie between 150 deg. and 400 deg. C. (302 and 752° F.), and the larger part of it, at least 75 per cent of the whole, must not boil below 235 deg. C. (455° F.)

At least 10 per cent of its constituents must be acids dissolving in caustic soda lye of 1.15 Sp. Gr. (Oils of the creosote or carbolic acid type.)

At 15 deg. C. (59° F.) the oil of tar must be completely fluid and free from fatty constituents so that when poured out on the dry end surface of a timber, it will soak into the wood immediately and leave only an oily residue.

It must further be as free as possible from naphthaline and at 15 deg. C. (59° F.) must give off no naphthaline.

It must contain no oil of specific gravity less than 0.9 (or at least not over one per cent of such oils), while the specific gravity of the tar oil itself at 15 deg. C. (59° F.) must lie between 1.045 and 1.10.

It must also be of such consistency that it is retained in the pores of the timber as much as possible after impregnation. Oils made from bituminous substances may be added to the mineral tar oil to an amount not exceeding 15 per cent, but the mixture must possess the same properties as are specified above for mineral tar oil.

Guarantee as to the Absorption of Oil of Tar.

It is guaranteed that the average amount of tar oil absorbed in each charge will be:

a.	For a pine tie 16 x 26 cm. and 2.7 m. long	30 Kg.
	For a beech tie of same size	30 Kg.
	For an oak tie of same size	8.5 Kg.
b.	For a pine tie 16 x 26 cm. and 2.5 m. long	28 Kg.
	For a beech tie of same size	28 Kg.
	For an oak tie of same size	8.5 Kg.
c.	For a pine tie 14 x 24 cm. and 2.5 m	23 Kg.
	For a beech tie of same size	23 Kg.
	For an oak tie of same size	7 Kg.
d.	For timbers of various sizes per cubic metre:	
	For pine	270 Kg.
	For beech	270 Kg.
	For oak	85 Kg.

These provisions apply to sound timber felled in winter.

In order to determine the amount of oil of tar absorbed, the timber is twice weighed, once before it is put into the impregnating cylinder and again just after it is removed therefrom. The difference in weight is the amount absorbed.

If, in the case of any charge, the timber fails to absorb five-sixths of the guaranteed quantity of fluid, the inspector may require the process to be at once repeated.

Any final deficiency of tar oil absorbed shall be deducted from the estimates at the rate of 10 marks per 100 kilogrammes ($1.09 per 100 lbs.).

D. IMPREGNATION WITH HEATED DEAD OIL OF TAR CONTAINING CARBOLIC ACID,—ACCORDING TO A PROCESS INVENTED AND INTRODUCED BY JULIUS RUTGERS.

The treatment consists of two parts:

I. The drying of the timber, i. e. withdrawing the moisture from the wood by means of heated oil of tar and the action of an air pump.

II. Pressing the oil of tar into the wood by means of a pressure pump.

I. Drying the Timber.

The timber to be impregnated is introduced into the impregnating cylinder which is then hermetically sealed. A vacuum of 60 cm. (23.6 in.) of mercury is then produced and kept up for 10 minutes. The oil of tar, previously heated, is then introduced into the cylinder, to such a height that it cannot be "sucked over" by the air pump, the vacuum being continuously maintained.

The admission of the heated oil of tar is completed at a single operation or with interruptions, according to the dryness of the timber.

During or subsequent to the filling, the oil of tar in the cylinder is heated to a temperature of not less than 105 deg. C. (221° F.) and not more than 115 deg. C. (239° F.) by means of steam, using a coil lying in the lower part of the impregnating cylinder, or a tubular boiler placed underneath. This heating should occupy a period of at least 3 hours. After the required temperature is reached in the cylinder it must be kept up for a further period of 60 minutes, either with or without a vacuum, according as it may be necessary in order to ensure the absorption of the specified amount of oil of tar.

As soon as the filling of the impregnating cylinder with heated oil of tar begins, it must be connected with a condenser, which serves to condense all the aqueous vapors that escape from the wood and to conduct all the water of condensation into a vessel intended to receive it. This vessel is provided with a water gauge on which the amount of water evaporated may be read off.

II. Pressing in of the Oil of Tar.

After the drying of the wood, i. e. the removal of water from the wood is completed,the tank is filled completely and a pump is put into operation which will produce a pressure of at least 7 atmospheres (103 lbs. pr. sq. in.). This

pressure must be kept up at least 30 minutes for pine or beech wood and 60 minutes for oak, or a longer time if it shall prove necessary, in order to insure the absorption of the specified quantity of oil of tar.

This completes the impregnation of the timber and the oil of tar is then drawn off.

Composition of the Oil of Tar to be Used.

The oil of tar must be made from mineral coal tar and must contain not over one per cent of oils that boil below 125 deg. C (257° F). The boiling point of the oil of tar as a whole must lie between 150 deg. and 400 deg. C (302 and 752° F), and the larger part of it, at least 75 per cent of the whole, must not boil below 235 deg. C (455° F).

At least 10 per cent of its constituents must be acid dissolving in caustic Soda lye of 1.15 Sp. Gr. (Oils of the creosote or carbolic acid type.)

At 15 deg. C. (59 deg. F.) the oil of tar must be completely fluid and free from fatty constituents so that when poured out on the dry end surface of a timber, it will soak into the wood immediately and leave only an oily residue.

It must further be as free as possible from Naphthaline and at 15 deg. C. (59 deg. F.) must give off no Naphthaline.

It must contain no oil of specific gravity less than 0.9 (or at least not over one per cent of such oils) while the specific gravity of the tar oil itself at 15 deg. C. (59 deg. F.) must lie between 1.045 and 1.10.

It must also be of such consistency that it is retained in the pores of the timber as much as possible after impregnation. Oils made from bituminous substances may be added to the mineral tar oil to an amount not exceeding 15 per cent, but the mixture must possess the same properties as are specified above for mineral tar oil.

Guarantee as to the Amount of Oil of Tar Absorbed.

It is guaranteed that the average absorption of oil of tar absorbed in each charge shall be:

a.	For a pine tie 16 x 26 cm. and 2.7 m. long	36 Kg.
	For a beech tie of same size	36 Kg.
	For an oak tie of same size	11 Kg.
b.	For a pine tie 16 x 26 cm. and 2.5 m. long	34 Kg.
	For a beech tie of same size	34 Kg.
	For an oak tie of same size	10 Kg.
c.	For a pine tie 14 x 24 cm. and 2.5 m. long	28 Kg.
	For a beech tie of same size	28 Kg.
	For an oak tie of same size	8 Kg.
d.	For a cubic metre of pine timber of various sizes	325 Kg.
	For a cubic metre of beech timber of various sizes	325 Kg.
	For a cubic metre of oak timber of various sizes	100 Kg.

The absorption guaranteed above is based on the assumption that the timber is felled in winter, and is sound.

The determination of the amount of oil of tar absorbed by the wood may be ascertained not only by weighing the timber before and after treatment, but also by measuring the quantity of oil of tar used in the process.

By the first method we must take into account the amount of water evaporated from the wood while it was being dried in the heated oil of tar and which was collected in a special vessel after condensation.

The weight of this water shows the loss in weight sustained by the wood during the process of drying in the hot oil, and this weight must be subtracted from the weight of the timber before its impregnation.

For determining the amount of tar absorbed the following method is used:

At the beginning of each impregnation the quantity of oil in the oil tank is determined by means of the floating gauge attached to it. After the process of impregnation is completed, the oil not absorbed by the timber is pumped back into the oil tank and the level of the oil is again measured.

The difference represents the amount of oil of tar absorbed by the ties.

In case the amount of oil of tar absorbed is less than five-sixths of the specified amount the inspector may require the process to be at once repeated.

Any final deficiency in oil of tar shall be subtracted from the estimates at the rate of 10 marks per 100 kg. of oil of tar ($2.40 per 220 lbs).

DISCUSSION.

Mr. Lyman E. Cooley—Have any experiments been made with the residuum of oil from the petroleum refinery?

Mr. Chanute—I do not know whether direct experiments have been made with residuum. A process was patented about 18 years ago by Mr. Andrews, who was creosoting at that time in New York. He, I think, never applied it upon a practical scale, and he was discouraged by the statement of chemists that there was no antiseptic property in it whatever.

I myself made an examination about 20 years ago as to the preservative effect of crude petroleum. It had been reported in the oil regions that the wooden tanks which were used for storing petroleum never decayed, and I went out to Titusville to ascertain what the facts were. I found that those tanks, so long as they served for the storage of petroleum, did not decay, but that after they were abandoned as petroleum reservoirs they did decay. The same results were observed in connection with the ties laid in the track. There were a number of side tracks at Titusville, some of which had been used in early days for loading oil when business was active. These had been thrown out of use, and in such cases I found the ties badly decayed. In the tracks which had been laid at the same time, but which had been in current use, I found the ties well preserved after ten or eleven years' exposure, which indicated to my mind that petroleum was an oily substance which was a preservative so long as it continued liquid, but that when it evaporated it left no antiseptic properties behind it.

Mr. Cooley—What is the experience in wood preservation in tropical countries under heavy rainfall?

Mr. Chanute—I think creosoting alone has there proved an efficient remedy; I do not know of any experiments with mineral salts, but I should expect that under the heavy tropical rains and fierce suns they would wash out and leave the wood unprotected.

Mr. Cooley—On the Panama road they are not able to have any considerable duration of ties; they only last about half as long as in this climate.

Mr. Chanute—I fancy not. I think they would find that creosoting would prove effective in that climate. That poorest of wood, that which decays in this country in two years, the beech, is proved to last an average of twenty-seven years when thoroughly creosoted.

Mr. Charles L. Strobel—What is the present practice in India?

Mr. Chanute—India almost entirely lays creosoted ties which are

imported from England. The ties are cut in Russia, creosoted in England and exported to India.

Mr. F. H. Bainbridge—Is there any indication that these preservative processes injure the strength of the timber?

Mr. Chanute—They injure it a little, more especially the mineral salts, and it is a very nice point to inject a large quantity thoroughly without injuring the strength of the timber. I do not recommend the use of any of the mineral salts for bridge timber exposed to either tensile or shearing strains.

When some years ago the bridge at Havre de Grace was prepared by burnettizing, the timber was so much impaired that the lower chords broke all to bits, and the same experience has been had in a number of other cases. For top chords, compression pieces, and for plank, I think the system would do well, but it certainly impairs the strength of the timber.

Mr. S. G. Artingstall—Does that refer to creosoting?

Mr. Chanute—That refers more to mineral salts; that is, copper, mercury and zinc. For structural work the tensile strength deteriorates. The treatment is not so injurious to the compressive strength, although the timber is weakened. It becomes weaker in tension but not in compression.

Mr. W. H. Finley—Which bridge at Havre de Grace do you refer to?

Mr. Chanute—I refer to the first railroad bridge of the Philadelphia, Wilmington & Baltimore, which had to be renewed in a very few years because of the difficulty in the breaking of the timber. That was also one reason why the Philadelphia, Wilmington & Baltimore gave up the burnettizing works which it had erected. It burnettized its own ties. It aimed to do it thoroughly well, and it did so over well that it made the ties as brittle as carrots, so that they would break in two when tossed from a railway car.

The Chair—Does the solution enter the wood in the direction of the grain, or in the opposite direction?

Mr. Chanute—Much the largest proportion of the solution enters through the sap ducts at the ends of the ties. Some enters through the medullary rays, but much more enters at the end. That has been thoroughly tested by painting the ends with several coats of lead and allowing the lead to dry and then treating the tie. It then took one-quarter as much as it did when the ends were left open, and this led the French some years ago to adopt the practice of sawing off an inch at each end of the tie in order to cut off all the dirt and open up the pores, to make sure of penetrating the wood thoroughly. That has been since abandoned, because it was found that seasoning answered as well.

The Chair—As the solution goes into the ends—in the case of piling which I have in mind more than anything else—in treating piles is it necessary in order to obtain good results, that they be sawed or hewn?

Mr. Chanute—Not absolutely, although Mr. Putnam, who carried on the work at Pascagoula for many years, was in the habit of so managing the steam as to crack the pile in order to open up the sap ducts to his creosote.

Mr. Cooley—You do not recommend any process except creosoting for marine work?

Mr. Chanute—No, sir; that is the only efficient process; and even then it is only efficient if the right kind of creosote is used. We had a notable instance of that in Pensacola, where the United States dock was eaten up by the teredo in four years, while the piles in the Mobile and New Orleans bridges had stood for twelve years.

Mr. Cooley—It takes a heavy dose?

Mr. Chanute—It takes a heavy dose, and it requires a peculiar quality of creosote only. The difference between the Mobile and New Orleans bridges and that at Pensacola, in lasting quality, was due to the different origin of the oil. Creosote has been used largely for bridges and trestles in the southern states and with entire success. Docks have been built, as well as trestles and bridges, of creosoted timber.

Mr. Bainbridge—How about the expense? Is the expense increased by the extra cost of the plant for very long timber?

Mr. Chanute—No, sir; most plants are prepared to treat timber about 100 feet long; it takes a little more time to treat a long stick than a short one.

Mr. E. E. Russell Tratman—I think the society may congratulate itself on having this very valuable paper on an important subject by Mr. Chanute. I notice he refers to the creosoting plant at Perth Amboy. I was told a few days ago that the Lehigh Valley Railroad had abandoned its plant, and that a new German company was exploiting a new process called the Hasselmann process. What the process is I do not know. There is another process which I did not hear Mr. Chanute mention, and that is the vulcanizing process which was used a few years ago quite extensively on the New York elevated railroads. One of the large German companies sent some representatives over here a few years ago and there was great talk at that time that the process would be introduced abroad. My understanding is that the report on that subject was entirely unsatisfactory when it came to be investigated scientifically. Within the past year or two, however, there has been a large plant put in use in England, I think for treating large timbers for ship-building. I do not know whether Mr. Chanute has investigated that process or not.

Mr. Chanute—Yes, I have. That was presented to me twenty-five years ago by the original inventor of the process. It was invented by Mr. Robbins, who originated and patented, in 1865, the Robbins creosoting process, which failed. He reasoned that having failed in preserving wood by injecting a small quantity of creosote, it would be preferable to endeavor to preserve wood without injecting anything at all, and so in 1875 he patented the vulcanizing process. The

leading timber preserver in Germany, Mr. Rutgers, sent an agent to this country to investigate the process. The agent had a number of pieces of timber prepared under his inspection, and he tested the heat in the interior of the tie by boring in a number of holes and inserting thermometers, but most of them got broken. Finding that to be a failure, he then had some fusible plugs made of tin and bismuth, which melted at various degrees of heat, and he bored rows of holes side by side in the wood and in them he inserted these little plugs of bismuth and tin. Some of those holes he plugged up, and some he left open, in order to determine the temperature that penetrated into the interior of the wood. He found that the temperatures which were claimed to penetrate into the interiors of the wood were not obtained, and that the results which were claimed—that sufficient heat penetrated to the interior to coagulate the albumen and to partially distil the constituents of the sap into antiseptics—did not exist, and he so reported, and Mr. Rutgers did not buy the process. Some other gentlemen in Berlin, however, were more favorably impressed than he and they bought the process and built a plant at Berlin. Subsequently the then owner of the process went to England and is said to have sold the patents for twenty thousand pounds ($100,000), and large works have been erected, with what practical results I am not advised.

With regard to the Lehigh Valley creosoting plant: the Lehigh Valley Railroad erected that plant, to treat its own piles and timbers, at Perth Amboy, and all timber it treated for two or three years was then treated with very good success. Subsequently, to keep the plant busy and earn the interest on its first cost, which was said to be $83,000, the road organized a department to run it. That department has been treating timber for quite a number of years and has done, I believe, some very good work, but I have been told that it was found that it did not pay; that competition cut the price so much that contracts were accepted which yielded no profit; and a year and a half ago the Lehigh Valley Railroad shut down its plant. The road has now leased the plant to the people who are introducing the Hasselmann process into this country. This is the process which I mentioned, consisting of boiling the timber with sulphate of copper and sulphate of iron, with some other substances. That process is on trial. It has been experimented with the last three years in Germany, but of course the practical results are not yet known.

A Member—What is the comparative length of service of ties—that is, taking one of oak, and another of some comparatively cheap and useless timber for such service, and treating it with creosote, so that the cost of the comparatively cheap timber tie would be the same as the oak tie?

Mr. Chanute—Well, it is not possible to creosote thoroughly for the difference in first cost of the two kinds of ties. It is possible to take a beech tie, which will rot in two years, and treat it and so fill it with creosote that it will last twenty-five to thirty years, but at a

very considerable cost—at a cost as in France of 64 cents, at a cost as in Germany of 56 to 59 cents. Then it is not much more economical, including interest, than a non-treated oak tie which will last with us eight or ten years.

The Member—The question is, whether our forestry laws will bear on the question of the future use of treated ties?

Mr. Chanute—Yes, there is no doubt whatever that we shall be compelled, and that within a few years, to resort to the preparation of cheap woods which have hitherto not been in demand, and which are yet cheap; and that by careful treatment we can make these outlast the best white and burr oak.

Mr. W. W. Curtis—While listening to Mr. Chanute's interesting paper and the discussion thereon, several things have occurred to me which may be of interest to the Society. With reference to the effect of burnettizing upon the strength of timber, I want to speak a word of caution. While the general impression as to the effect of treatment on strength in tension and cross bending is as Mr. Chanute has stated it, very few experiments in this direction have ever been made, to my knowledge. Because the timber burnettized twenty years ago proved to be brittle, it does not follow that timber as now treated would be so. I am somewhat doubtful as to the chemicals injuring the strength of the timber. It seems more probable that such injury is due to the heat used; and as even higher heat is used in creosoting, it is claimed without injuring the strength, I would suggest that it is desirable to determine the facts by present tests, instead of assuming that the matter is already proven. I notice statements of laboratory tests of timber treated by the Hasselmann process, in which the strength apparently is not impaired. I doubt if burnettizing is any more injurious.

The Atchison, Topeka & Santa Fe Railroad at its Las Vegas works, treats not only ties, but piles and bridge timbers as well; indeed, all bridge material except the stringers, which are Oregon fir and are quite durable in their natural condition. The manager of the works advises me that they are well satisfied with the results. The piles are used in both wet and dry locations. Possibly this experience with timber and piling so treated has not been long enough to determine its real value. This road proposes using treated ties on the entire system this year; all being treated by the zinc tannin process.

I am a firm believer in the use of the process which the author of the paper is using, and particularly a believer in the three injection process rather than the two injections. This is covered perhaps in the paper, but for the information of those who do not know, I might say that the original process was an injection of the zinc and the glue in one mixture, which was then followed by an injection of the tannin. Now, the process is modified by injecting the three solutions separately, which in my judgment is a great improvement.

Mr. Chanute has already referred to the fact that the simple bur-

nettizing process, that is, where the zinc chloride alone is injected, will probably give very good service under favorable conditions in this country. There are but two roads I believe using this process in this country, the Southern Pacific and the Chicago, Burlington & Quincy in its Black Hills work, both of which roads are working under favorable climatic conditions. The Southern Pacific for five or six years, has been using the burnettized ties on its Oregon line and in Northern California, and I was told last week that so far the results have been very satisfactory. The company has had no reason to doubt the efficacy of the treatment for that part of the country. The lines in Oregon are working under rather severe conditions climatically.

The only other point that occurred to me was with reference to the matter of testing of ties to determine the amount of the chloride that had been injected. The officers of the Southern Pacific road have devised a method of testing which is so simple that the foremen in charge of the works are able to make the tests. The sample borings from various ties are each burned to an ash, over a gasoline jet, in a porcelain roasting dish, in contact with the air. The ashes are carefully collected in a platinum cup, distilled water added, with a slight excess of hydrochloric acid, converting the zinc oxide into zinc chloride. It is then filtered into a test tube and the zinc hydrate thrown down with sodium carbonate, making a white flocculent precipitate. The liquid is then made up with distilled water to 3 drachms. The resulting milky liquid is compared with standard liquids in tubes of the same size as the test tubes, each tube containing 3 drachms. The standard liquids are graded to represent .06, .09, .12, .15, .18, .21, and .24 pounds of zinc chloride per cubic foot of timber. This test is said to be perfectly satisfactory.

Mr. J. H. Warder—I would like to ask if Mr. Chanute can give us an explanation of how in his process he uses three solutions?

Mr. Chanute—There is a fact well established from hundreds of experiments with an experimental plant which we have, that the addition of gelatine to the chloride of zinc solution made the latter less fluid, rather viscid, and that the solution therefore did not enter into the wood in the same quantities, nor penetrate as far; therefore I changed the process, which was still, however, under the original patent, as the specification covered fully the change I made. This was to inject first a solution of chloride of zinc, and that we make just as limpid as water, so that when held up in a glass it is as clear as the Chicago water is now. That is injected as a first solution, after the wood has been prepared first by steaming and then by vacuum in order to clear the pores of the dead air as far as possible. The injection is done under a pressure of 100 pounds and a temperature of 150 degrees F. I would say that we find we can extract more sap from a partially seasoned tie than from one fresh cut; the one fresh cut has three times as much sap, but we can not get it out, and I attribute that to the fact that when the tie is fresh cut, it is im-

practicable to heat the interior of it sufficiently to change the watery portions of the sap into steam. We are therefore not placing motive power behind to push the sap out of the sap duct; while, after it is partially seasoned, air has flown in, and by heating that air it acts in expansion and pushes the sap out, so that after a period of steaming, (in order to heat the timber and the air inside of it,) we create a vacuum, during which steaming and vacuum we find that the sap comes off abundantly.

In our own plant at Mount Vernon we measure the sap by catching it in a tank with an attached glass tube, so that from each load we know just how much sap is being extracted, including some condensed steam that passes off with it. Then the chloride of zinc solution is admitted to the cylinder, and a pressure of one hundred pounds to the inch is placed upon it. That pressure is continued for about three hours, with an initial temperature of 150 degrees F. At first the timber absorbs it readily, then little by little it refuses until, towards the last, the pump has to work at its lowest possible speed in maintaining the pressure. We then know that the operation is terminated; but in order to make sure of the quantity which we desire to put in, and knowing the quantity of wood that is in the cylinder, the amount of the solution which we want to inject is put into the measuring tank, and from that measuring tank we pump until the entire quantity has been injected.

After the chloride of zinc has been absorbed the quantity of that injected is checked in two ways, first, by observing the floats in the tanks which show the exact amount, being graduated in hundreds of feet; then again, and, secondly, at our new works, by weighing the ties before they are treated and weighing them afterwards, it is certain that we have injected the required quantity. We then pump compressed air into the retort and blow the solution back into the storage tank, so as to clear the cylinder of it. Then the second solution is admitted—that of gelatine—and a pressure of 100 pounds to the square inch is put upon that. As I stated in my paper, it does not go very far into the wood, because the wood has been pretty thoroughly filled by the first solution. The second solution penetrates perhaps three-quarters of an inch. Then that solution, after a half hour or an hour's pressure, is blown back into its tank and the third solution is admitted, on which a pressure of 100 pounds to the inch is also applied, so as to force it in; then that is blown back into its proper tank and the operation is considered completed. It takes about twelve hours. The doors of the cylinder are then opened and the ties are hauled out.

The moment they are hauled out they begin to "bleed"; that is to say, the air which has been occluded in the sap cells and which has been compressed to 100 pounds to the inch by the various solutions that have been forced in, re-expands and forces out little bubbles of the solutions at the ends. The ties come out evaporating abundantly. They begin at once to dry, so that if a buggy load is

weighed next morning after treatment it does not weigh as much as immediately after it comes out of the retort.

We have found that the method of weighing in and out is a very great improvement and a very great check, so that it has enabled us to work for an entire year and to hit within less than one per cent of the quantity we desired to inject.

Mr. L. H. Flanders—I would like to ask Mr. Chanute to re-state the average German price of the ties treated by the zinc process.

Mr. Chanute—The price paid for treatment in Germany for a first-class pine 15.6 cents and 18.8 cents for beech in straight burnettizing. For the "zinc creosoting" process the price paid is 19.2 cents for pine; 20.4 cents for beech, and 15.6 cents for oak. Those are for the two zinc processes.

Mr. Flanders—In this country, how does the price compare with the price abroad?

Mr. Chanute—We are doing it almost as cheaply in this country as in Germany. I was rather surprised at that, as I thought it ought to cost more.

Mr. Bainbridge—I would like to say in regard to the Southern Pacific, that it was one of the first roads to take up this tie treating. They have to depend, I believe, almost altogether on the pitch pine for ties. It is a timber that looks very much like white pine, but it only lasts for a number of years.

Prof. W. D. Pence—Reference has been made in the discussion, and I believe also in the paper, to the question of preservation of piles from the attacks of the teredo. I should like to have Mr. Chanute's judgment as to why those piles failed. In my experience, the creosoting, unless it is very thoroughly done, fails inside of a very few years. I have in mind some creosoting which was done in 1876, and only a very small number of the piles survived at the end of sixteen years. I should like to have Mr. Chanute's analysis of how creosoted piling failed.

Mr. Chanute—I do not know. I have never had any experience with creosoting, but I understand in a general way that the failure of creosoted piles arises from one of two causes, viz: either the creosote has not been of the proper quality—and Mr. Boulton insists that that is the reason why they fail—or, second, there has not been enough of it put in. The sawed section of creosoted piles shows the discoloration from creosote only in spots. There are certain portions of the wood which are of more open grain than others and the creosoting fails to impregnate the pile uniformly. For this reason there are portions (if the pile has not enough creosote) which are not so objectionable to the teredo and where he gets in and does his work; but if the pile be thoroughly and completely filled with creosote, and it is creosote of the proper quality, the teredo does not get in and he does not eat the wood.

Prof. Pence—I suppose in this particular structure another element came in. Enough of the piles failed so that they had to be

renewed, and alongside of the better creosoted piles were a lot of elm and other piles, so that perhaps the teredo had sufficient food in these. What sort of a ward would that constitute for the neighboring piles?

Mr. Chanute—I cannot say about that.

Mr. Cooley—I had some correspondence with Ricker, Lee & Company, formerly contractors of the Drainage Channel, who had in charge, I believe, the creosoting works at Galveston, and they cited the case of Galveston Bay which the gentleman has alluded to, I believe. They stated that in that case there were seven or eight pounds per cubic foot used in the original creosoting, and I believe they claimed that twenty pounds per cubic foot were injected afterwards, in order to insure against the action of the teredo and a few of these last piles are intact today. I believe those are the figrues; I may be wrong, as to the exact amount that is stated in the correspondence. The general idea corresponds with the statement already made by Mr. Chanute, that we can hardly put in enough to insure absolute immunity.

Mr. C. L. Strobel—I believe the difficulty is that the heart wood does not take much creosote. I am informed that in the Lake Pontchartrain trestle work of the New Orleans & Northeastern Railway an attempt was made to treat the yellow pine timber. They used a certain quantity of creosote, and while the sap wood absorbed the creosote readily, and while there was no difficulty about getting the quantity prescribed into the sap wood, it was utterly impossible to get it into the heart. And furthermore, it seems that the degree of penetration is generally small, and whenever there is any framing to be done, especially if bolt holes are to be cut into the timber, that becomes a vulnerable point and the teredo gets in there. The creosote protects the outside shells and the ends of the piles very well, but is not found in the interior to any great extent.

Prof. Pence—I noticed yesterday that Mr. Rowe has presented the Society with a couple of specimens that he got from a Santa Fe tie that was put in in 1885, and taken out of the track in 1898. I think they are in the room, and the gentlemen interested in seeing specimens of ties that had been treated by the Wellhouse process, after they had been in the tracks for thirteen years, can find them here.

The Chair—Mr. Chanute, is it possible to get any benefit from creosoting other than under pressure? Will the injection by boring holes and filling with creosote produce any appreciable benefit in piling, for instance, or timbers of that kind?

Mr. Chanute—I understand not. I understand that the layers of the woody fibre do not admit of any liquid substance passing from one sap cell to the other. The attempt has been made very many times to bottle up creosote, or copper, or arsenic, or other salts in wood, by boring a hole and plugging it up, and the experiments have all proved failures. The sap cells do not communicate with

each other, except rarely, and any liquid confined in wood does not diffuse itself, so that it is absolutely necessary to employ pressure in order to force it in at the end and down the sap duct.

I have here a lag screw such as is used in the French railways, which I have brought, and I have also some dating nails, which is another features which I might have mentioned and did not. This is a German dating nail of last year. The Germans and French began by stamping the ends of their ties with the date, or the year in which they were treated. They found that would not do because the very tie which they wanted to know the age of, that is, the decayed tie, was the one in which the decay had so far proceeded that the date had become obliterated, and so they resorted to the driving of zinced nails. In Germany they drive in one; in France two, one at the works when the tie is treated, and another when it is laid in the track.

Mr. F. K. Vial—I would like to ask what is the effect of creosote or mineral salts on metal, in connection with ties or timber?

Mr. Chanute—I would say creosote is not injurious to metal in any way, so that timber creosoted does not affect metals. Timber treated with sulphate of copper does eat the spike to a limited extent. Chloride of zinc has some effect, the extent of which, however, is so small, that it does not in any way injure the fastening, and the Europeans are using the lag screw and the spike both upon ties which are treated with copper and chloride of zinc. Copper, however, is more injurious.

Mr. Vial—Chloride of zinc would not be injurious at all to I beams in connection with bridges?

Mr. Chanute—I think not.

XCI.

REBUILDING OF THE KINNICKINNIC RIVER SWING BRIDGE ON THE CHICAGO & NORTHWESTERN RAILWAY, AT MILWAUKEE, WIS.

By Francis H. Bainbridge.

Read April 4, 1900.

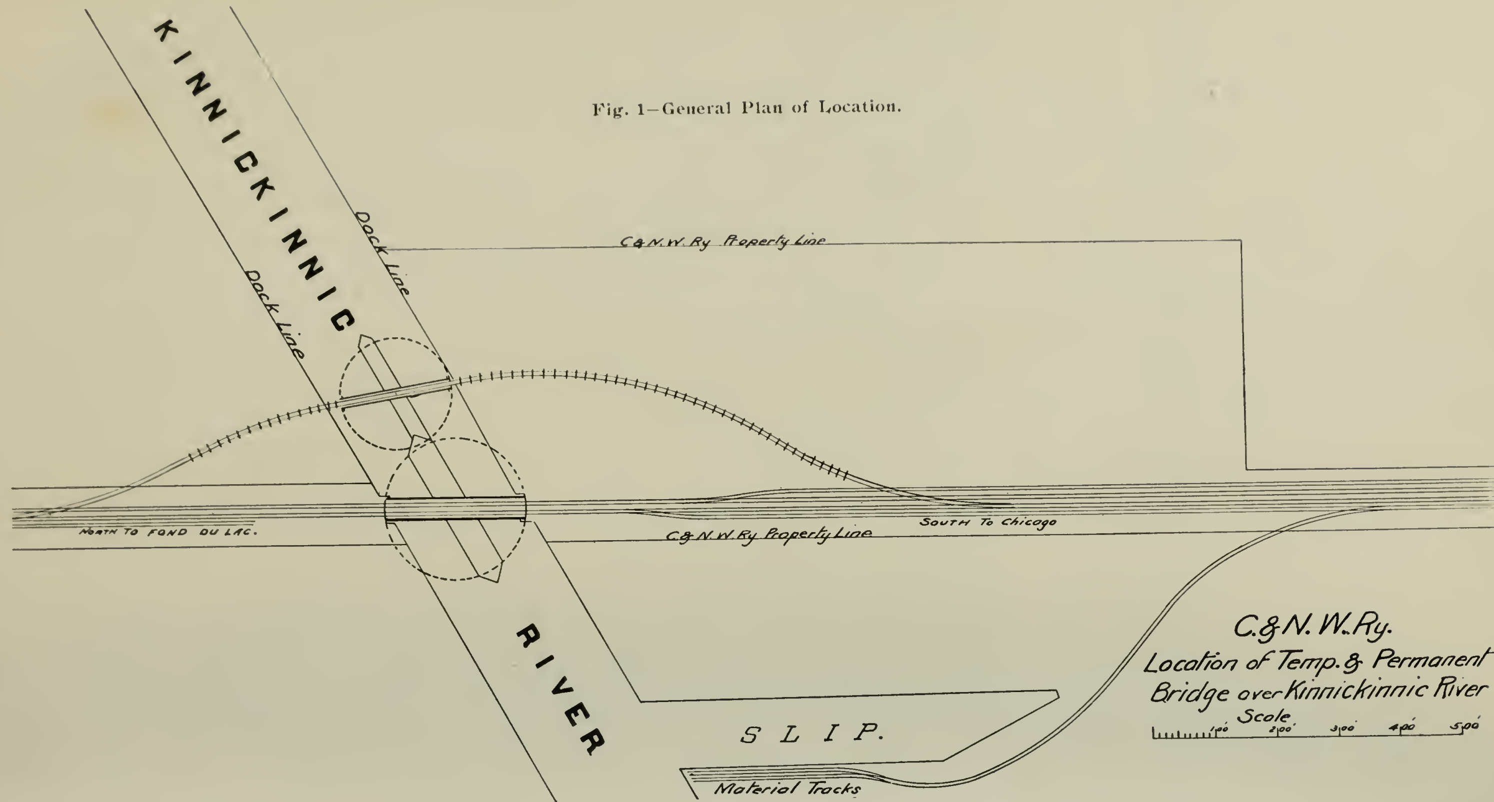
The Kinnickinnic river bridge is located on the Chicago & Northwestern Railway, Milwaukee Division, about three miles south of the Wisconsin St. station in Milwaukee, Wis. The old structure was a 177-foot single track through pin-connected swing bridge built in 1880. It was still at the time of its removal sufficiently strong to safely carry the increased weight of rolling stock, but the management of the Chicago & Northwestern Railway decided to replace the old span with a double track structure, the double track converging to a gauntlett track on the old structure.

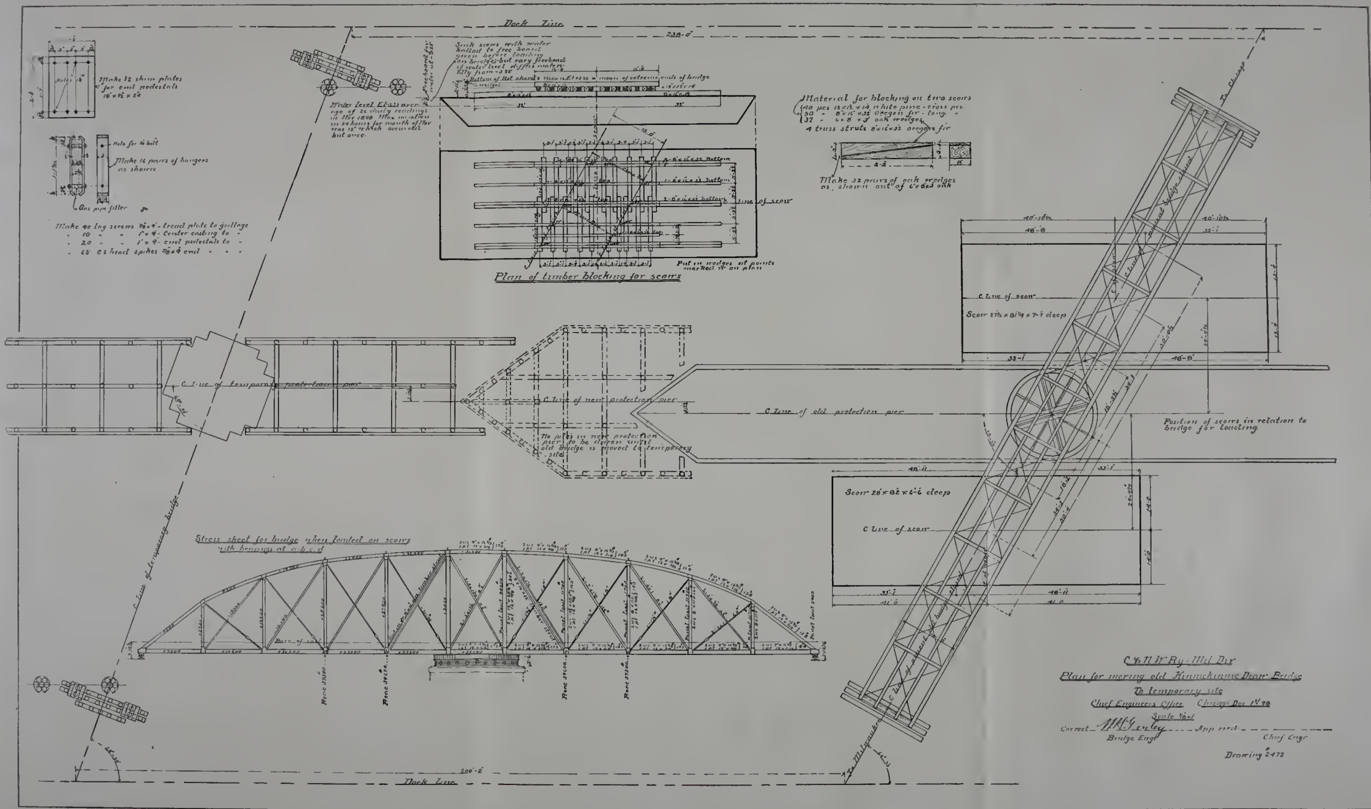
Fig 1 shows the position of the new structure, as well as the temporary trestle and the removed position of the old structure during the rebuilding of the new. It also shows the position of the slip and material tracks from which all the material used in connection with the new structure was handled, except the filling behind the abutments, which was of course directly unloaded from cars to its final position.

The old bridge with its track, drum wheels, tread and center, weighing in all 255,800 pounds, was moved a distance of 219 feet to its temporary position to carry the traffic of the road during the building of the new span. Fig. 2 shows the position of the scows on which the bridge was lifted from its supports, and floated to its temporary position, also the arrangement of the blocking, and a stress sheet of the trusses while supported by the scows. Fig. 3 shows the arrangement of the blocking on one of the scows. The operation of removal was, briefly, to fill the scows with water ballast and wedge up under the span; to pump water out of the scows until their buoyancy carried it clear of its supports, to move the floating bridge to its proper position, and lower to place by pumping water into the scows, at the same time allowing them to fill by removing plugs from their bottom.

The pumps used in pumping out water ballast were one steam pump with 6 x 14 in. water cylinder; one steam pump with 8 x 14 in. water cylinder running 80 revolutions per min.; two fire engines

Fig. 1—General Plan of Location.




Dock Line
Plan of timber blocking for scows
Material for blocking on two scows
Make 32 pairs of oak wedges as shown out of 6×8×3 oak
C Line of temporary protection pier
C Line of new protection pier
C Line of old protection pier
Position of scows in relation to bridge for loading
Stress sheet for bridge when loaded on scows with bearings at a.b.c.d.
C Line of temporary bridge
To Chicago
To Milwaukee
C & N W Ry - Mil Div
Plan for moving old Kinnickinnic Draw Bridge
To temporary site
Chief Engineers Office Chicago Dec 1st 98
Bridge Engr
Chief Engr
Drawing 2473

and two fire tugs, the latter using steam siphons only. The fire tugs and engines belonged to the fire department of the City of Milwaukee. The total amount of water pumped out of the scows to lift the bridge clear of the center pier was 92,600 gallons, or 1624 gals. per min. actual working time. The total amount pumped into the scows to lower the bridge was 69,400 gallons.

The time required to perform different parts of the work was as follows: The last train passed over the bridge at its permanent site at 9.05 a. m. Between 9.05 and 9.30 an ice jam was removed in the south channel in order to get the south scow under the bridge in its proper position; one fire tug and two scows, each with one fire en-

Fig. 3.—Blocking of Scow.

gine, were placed in position west of the bridge, and one fire tug and two pile-driver scows east of the bridge. The boilers on the pile-driver scows furnished the steam for the steam pumps.

Up to 9.30 a. m. there was no interference with railroad traffic over the bridge. At 9.30 all pumps were started, except on one fire tug, which was started at 9.35, and at 10.35 all water was clear out of the scows, and the bridge stood 2 ft. clear of the center pier. It was believed to be essential that practically all water should be removed from the scows to prevent the sudden shifting of the water from listing the scows. At 10.45 the bridge started down the channel, being towed by the two pile-driver scows, one on each side the protection,

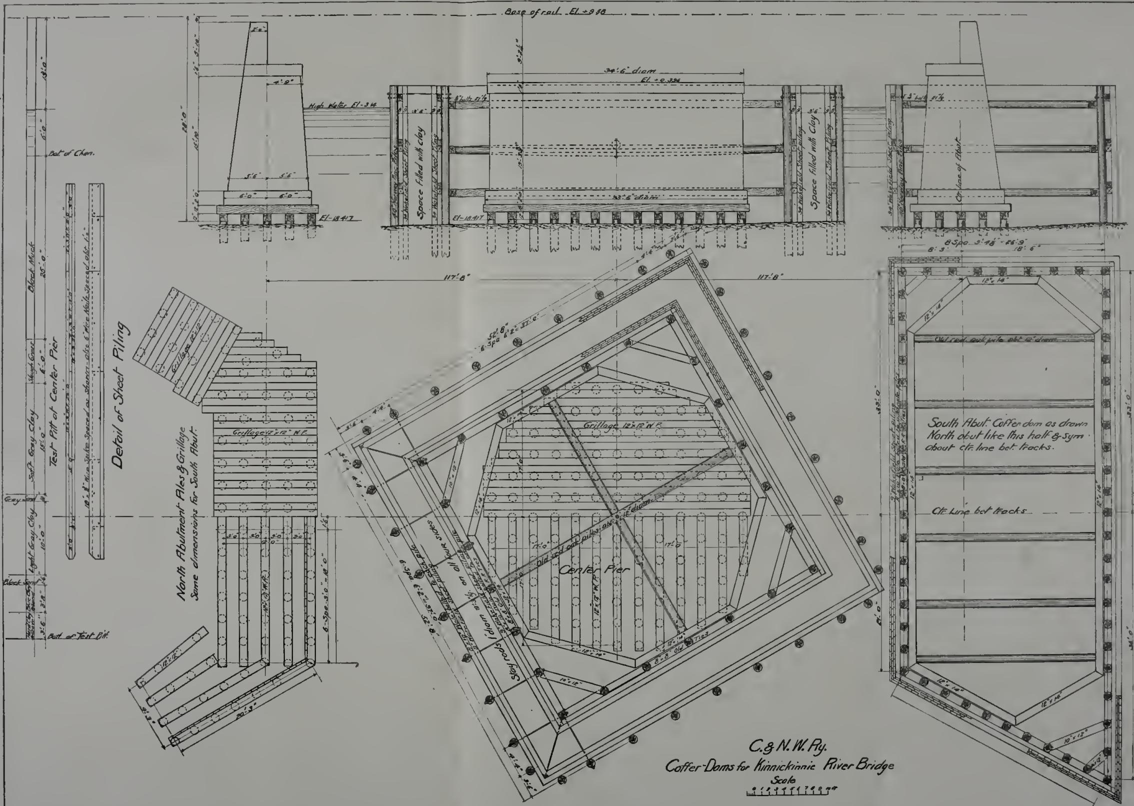
the pile-driver scows being drawn by lines running ahead to the temporary protection, the slack of the lines being taken up on the spools of the pile-driver engine. At 11.15 a. m. the bridge was over the temporary pier and abutments ready to lower. At 11.17 four plugs, each 3 in. in diameter, from each scow, were pulled, and all pumps started to pump water into the scows to lower the bridge. At

Fig. 4.—The Bridge Starting.

12 m. the bridge was landed, and at 12.10 p. m. the scows that supported the bridge in moving were released. At 12.20 p. m. the bridge was swung open by its own machinery to let the scows carrying the fire engines pass down the river, and at the same time the bridge was ready for traffic.

Fig. 4 shows the bridge at the beginning of its transit, and Fig. 5 in the act of being lowered to its temporary position. The moving was done Dec. 18, 1898.

The substructure of the new bridge is masonry laid on two courses of grillage, and supported on piles cut off about 16 ft. below mean water level. 65 ft. piles were used for the center pier, and 60 ft. piles for the abutments. These were driven where possible to 14 ft. below water level. For the center pier the final penetration under the blows of a steam hammer weighing 4,200 lbs., with a total weight of moving parts of 8,200 lbs., and a stroke of 3 ft., varied from nothing to .85 inches—average ¼ in. The greatest moving and fixed load for each pile is 17 tons. The abutment piles were 60 ft. long, and driven to 14 ft. below water level, the final penetration varying


Base of rail El. +9.40
High Water El. -3.14
Space filled with clay
Space filled with Clay
Test Pit at Center Pier
Detail of Sheet Piling
North Abutment Piles & Grillage
Same dimensions for South Abut.
Grillage 12"x12" W.P.
Center Pier
Stay rods 1" diam.
South Abut. Coffer dam as drawn
North abut like this half & sym.
about ctr. line bet. tracks.
Ctr. Line bet. tracks
117'-8"
Black Muck
Soft Gray Clay
Light Gray Clay
Bott. of Test Pit.
Bott. of Chan.
C. & N. W. Ry.
Coffer-Dams for Kinnickinnic River Bridge
Scale

from 3 in. to nothing, with an average of about ⅝ in. The possible load per pile is much less than for the center pier piles.

Fig. 6 shows a plan of the center pier and abutment coffer-dams. At the center pier 2 rows of triple lap Wakefield sheet piling 34 ft. long were used; at the abutment one row of the same 34 ft. long at the front and side, and 26 ft. long at the back. At the center pier the space between the two rows of piling was filled with clay. In pumping out the coffer dams a four inch plunger pump and a ten inch centrifugal pump were used. After the water was once out no trouble was experienced in keeping the dams from flooding with the 4 in. pump alone.

Fig. 7 shows an interior view of the center pier coffer dam, and Fig. 8 the abutment coffer dam.

Fig. 5.—The Bridge Being Landed.

All masonry was laid with a steam derrick, with a 40 ft. boom mounted on a scow 81¾ ft. long, 27½ ft. wide and 7 ft. 7 in. deep. Stone was unloaded directly from cars on the tracks next the slip, marked as material tracks in Fig. 1. The scow was moved by a forward line operated from the spool of its hoisting engine. Fig. 9 shows a plan of the derrick on the scow, and Fig. 10 a photograph of the derrick laying stone at the center pier. At the center pier 600 yds. were laid in 12 days by means of the derrick scow, although the river was filled with floating ice at the time. The capacity of the scows as ordinarily used was 60 yds. of stone.

Fig. 7.—Center Pier Coffer Dam.

Fig. 8.—Abutment Coffer Dam.

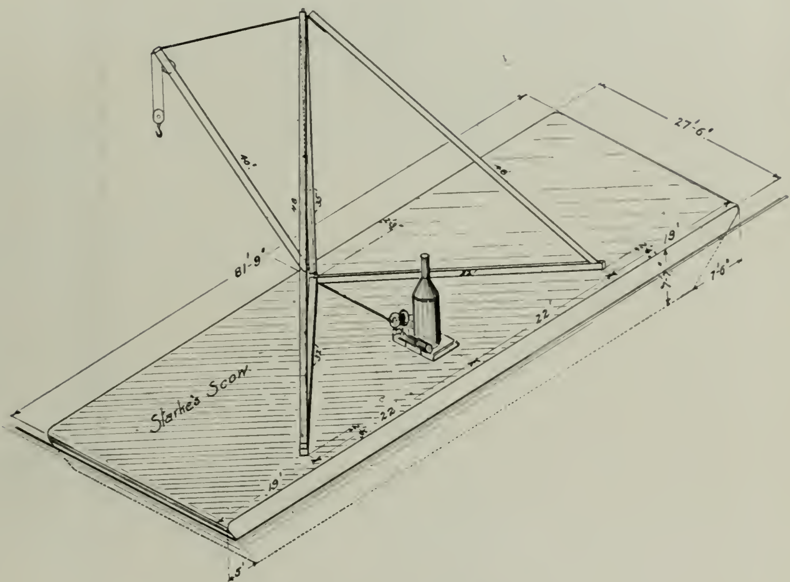


Fig. 9.—Plan of Derrick Scow.

Fig. 10.—The Derrick Scow.

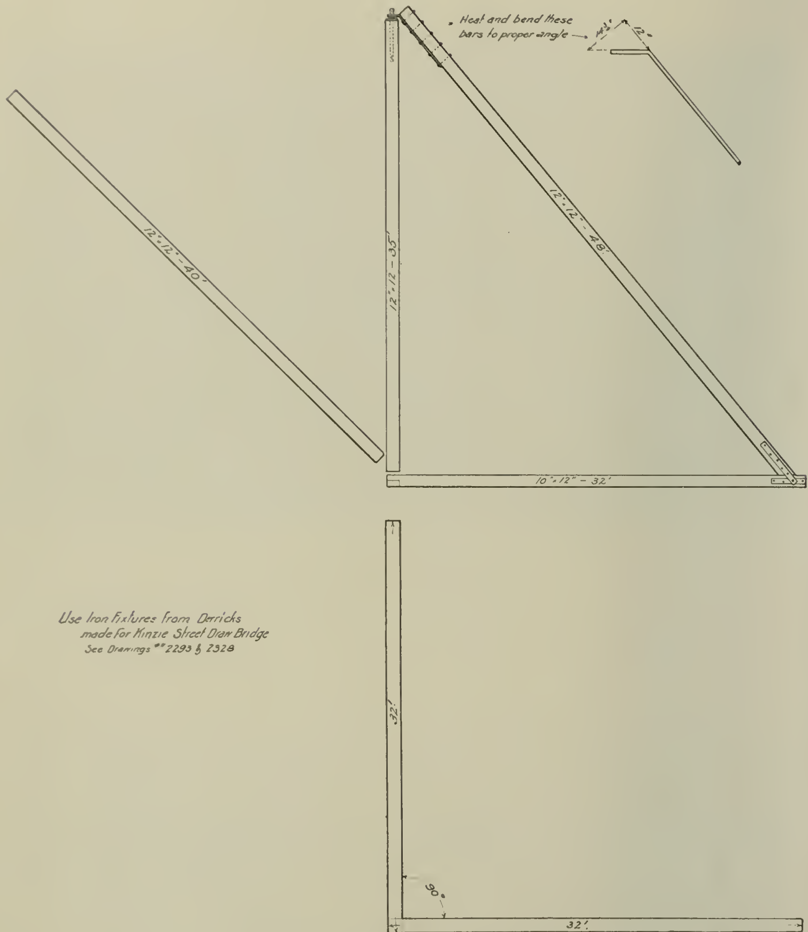


Fig. 9 a.—Detail of Derrick Scow.

THE SUPERSTRUCTURE.

The superstructure is a double track through rivetted lattice span 234 ft. over all. Fig. 11 shows a side view of the completed bridge, and Fig. 12 an end view. Rivetted lattice trusses are standard on the Chicago & Northwestern Ry. for single track fixed spans from 110 ft. to 160 ft., and for double track fixed spans from 110 ft. to 140 ft. Inasmuch as a fixed rivetted lattice span weighs from 15 to 20 per cent. more than a pin-span designed under similar conditions, some substantial reasons should exist for using the former. These are principally that rivetted lattice trusses have withstood the effects of the constantly increasing weight of rolling stock better than pin-bridges have, and that they are less liable than a pin-bridge to be

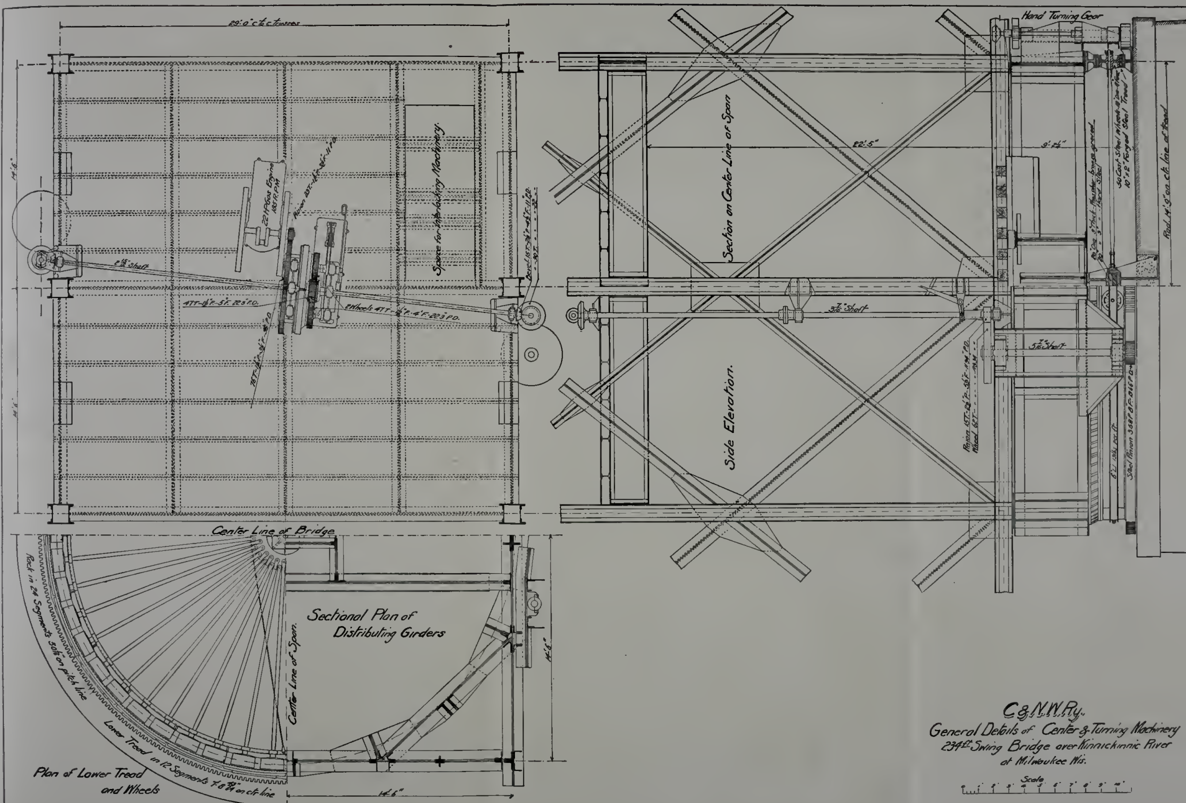

Center Line of Bridge
Sectional Plan of
Distributing Girders
Center Line of Span.
Plan of Lower Tread
and Wheels
Section on Center Line of Span
Side Elevation.
Hand Turning Gear
C.&N.W.Ry.
General Details of Center & Turning Machinery
234 ft. Swing Bridge over Kinnickinnic River
at Milwaukee Wis.
Scale

Fig. 11.—Side View of Bridge.

wrecked by a derailed train. Fig. 13 shows a rivetted lattice span at Fond du Lac, Wis., just after a collision had occurred on the bridge in April, 1898. A freight locomotive left the track and passed completely through the side of the bridge, as shown in the photograph, severing the web members at three panel points. Notwithstanding this the train which the engine had been hauling was successfully drawn off the bridge and four other trains run over it before any repairs had been made or supports supplied. Fig. 14 shows a side view of the same truss after bents had been placed under the unsupported floorbeams. It clearly shows the extent of the damage which had taken place. Some years ago Mr. Stowell, at that time bridge engineer for the state of New York, cited a number of cases in which end posts in lattice bridges had been completely broken without wrecking the structure.

Fig. 15 shows the effects of two accidents which happened to a rivetted lattice span on the Chicago & Northwestern Ry. at Daggett, Mich., both accidents being caused by logs projecting from a moving train. In both cases it would appear that a log projecting from a car struck the end post and caused the entire load of the car to shift, raking the whole side of one truss.

Fig. 16 shows a plan and elevation of the bridge center and turning machinery. The motive power is a 22 h. p. gasoline engine, with a maximum speed of 185 revolutions per minute. The multiplication from the engine pinion to the driving pinion is 27. Inasmuch as the gasoline engine can run only in one direction, two friction drums are provided for reversing the motion of the bridge, one or the other

Fig. 12.—End View of Bridge.

of the friction drums communicating power to the driving shaft, according as a hand lever operating wedge clutches on each of the two shafts is thrown forward or back.

About two-thirds of the weight is carried on the live ring of fifty cast steel wheels, the remaining one-third being carried at the center. Here the moving and fixed surfaces respectively are a 20 in. diameter phosphor-bronze disc, and a 20 in. diameter hardened steel plate. There is no adjustment for transferring weight to the

Fig. 13.—Accident to Bridge at Fond du Lac.

Fig. 14.—Fond du Lac Bridge Blocked Up During Repairs.

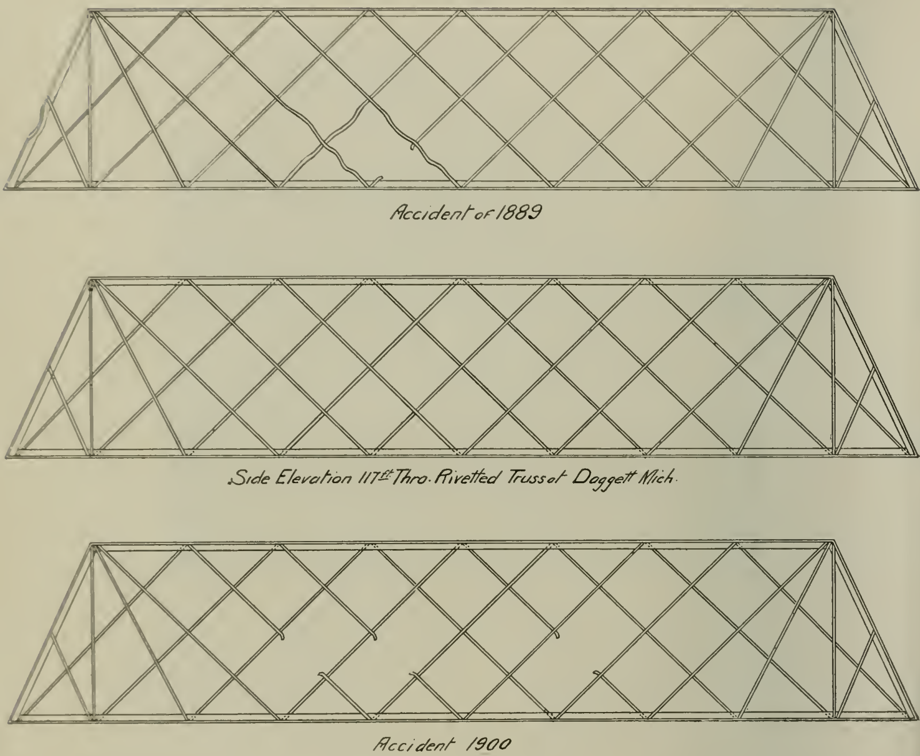


Fig. 15. Accidents to Bridge at Daggett, Mich.

center, the load at that point being transferred there by jacking up the bridge after it was finished and placing an additional 3-16 in. plate over the center casting. Previously the girder rested on the center casting, which carried the weight of the girders only.

There is no drum, strictly speaking, the upper coat tread being attached directly to the distributing girders, subsidiary corner girders completing an octagonal substitute for a circular drum.

Fig. 18 is a photograph of the engine and the two friction drums. The writer has had experience with two bridges operated by gasoline engines, and in both cases the engines have proved convenient, economical and satisfactory. The engines are built commercially principally for continuous service. On swing bridges the service is intermittent and it is essential that the engine should start off at the first trial. The operation of starting is to pour a small quantity of gasoline into a receptacle below the hand air pump. This receptacle is filled with wood fibre, which absorbs the gasoline. Then with half a dozen quick strokes of the air pump air is drawn through the

saturated wood fibre and forced into the engine cylinder, together with a certain quantity of gasoline vapor; next the fly-wheel is started by the operator; at the same time a match striker is struck with the hand. The flame of the match causes the first explosion, afterward an electric battery furnishes the spark. In order to make certain of an explosion of sufficient force to start the engine, the mixture of air and gasoline vapor must not vary beyond certain proportions, the proportions varying with the temperature. When the cylinder is heated an explosion is almost certain, no matter what the mixture; when cold, the mixture must be close to a fixed proportion. It required considerable experience to judge the requisite quantity to be admitted into the wood fibre, the quantity varying with the flashing point of the gasoline. When in continuous service almost

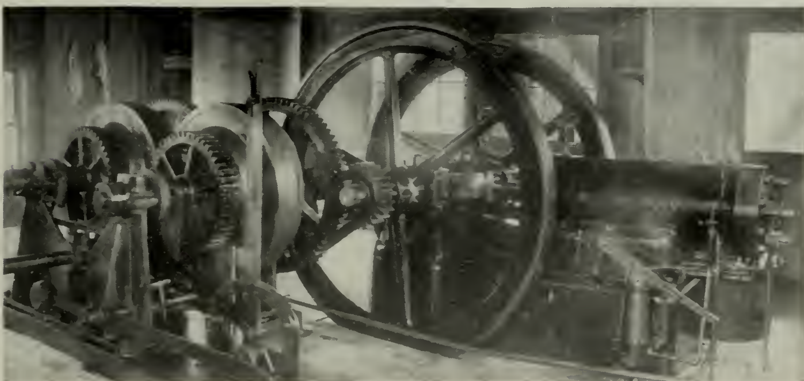


Fig. 18.—Engine and Friction Drums.

any quality of gasoline, or even kerosene, may be used, but for intermittent service we have found that gasoline with a flashing point of 84 degrees gives the best result. The cost of fuel for operating is less than 2 cents a swing, so that the cost of gasoline is of little importance.

If the engine-house is attached to the bridge trusses, it must be remembered that the rapid revolution of the fly-wheel causes considerable vibration, and the engine floor and adjacent parts of the truss must be stiff enough to resist it.

The span was erected on its own protection pier, the material being transferred from cars by the derrick scow, the entire center, floor system and bottom chord being set with the derrick. The rest of the iron work was piled upon the floor system already in place, and afterward erected with a traveller in the ordinary way (see Fig. 17).

The old span was taken down with the derrick, two loads sufficing to remove the whole span. All timber in the temporary trestle, piers,

Fig. 17.—Bridge Floor During Erection.

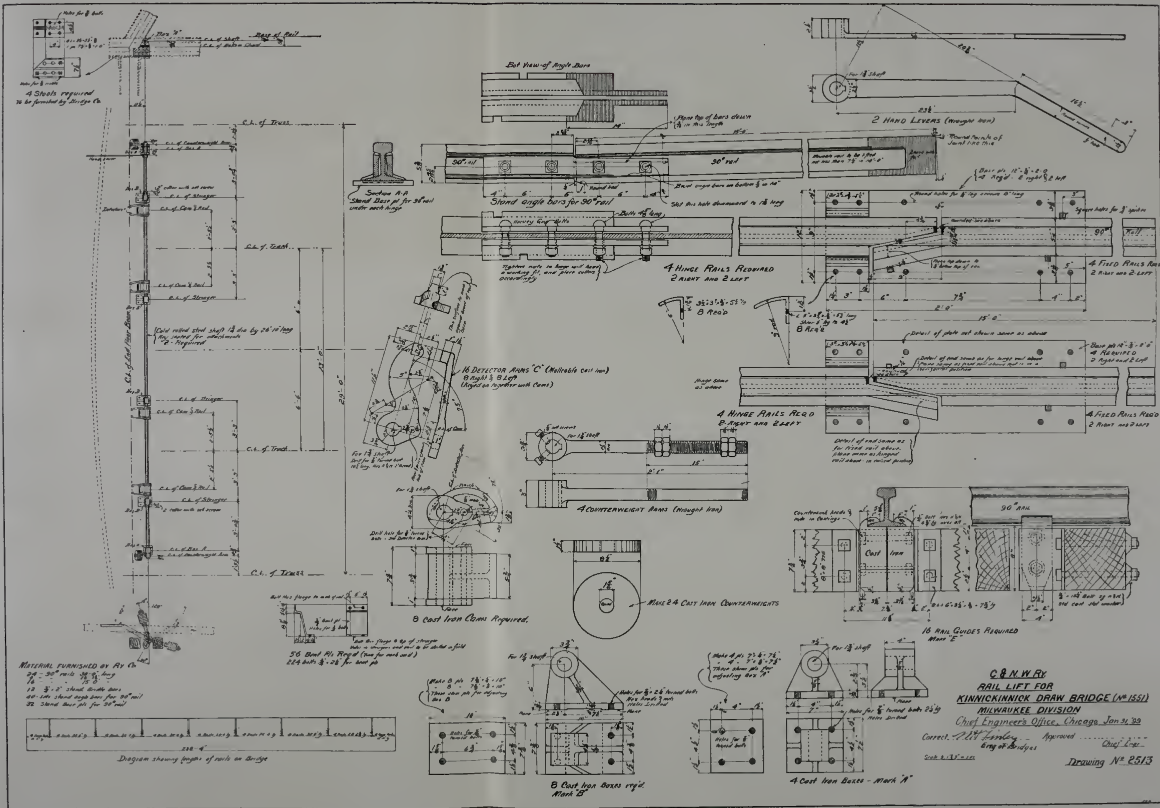
abutments and protection pier was rafted and floated to the slip shown in Fig. 1, and loaded there directly on cars with the derrick scow. The capacity of the material tracks was such that ordinary switch service of the Milwaukee yard was sufficient to handle the material, a work train being scarcely used at all except for the filling back of the abutments.

The structure was planned and designed by the engineering department of the Chicago & Northwestern Ry., under the direction of Mr. E. C. Carter, at that time principal assistant engineer, the work in the field being carried out by the writer, under the direction of Mr. W. H. Finley, engineer of bridges.

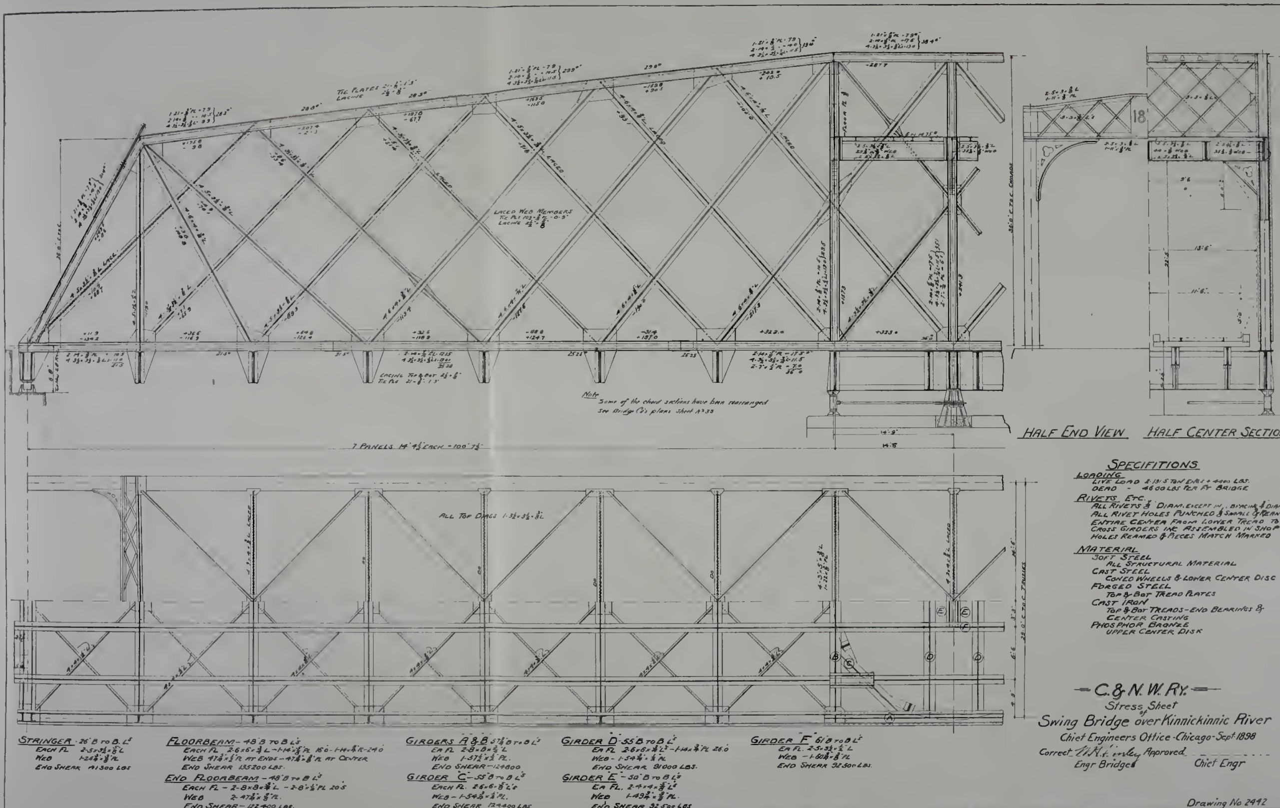
DISCUSSION.

Mr. G. P. Nichols—I notice that Mr. Bainbridge has placed an equalizer in his cross shaft; I want to ask him if he considers that a necessity, or, in other words, if in introducing this equalizer is he not apt to give rise to more trouble than he is obviating. Would it not be just as well to figure the size of the shaft so that it will be amply strong for the service required, but at the same time have enough torsion so that in itself it would be an equalizer?

Mr. Bainbridge—I do not know whether I am enough of a mechanic to answer that question, but all large swing bridges, so far as I know, are built with an equalizer, and with this equalizer, that we had there, if one of the pinions was thrown out of gear, the other pinion was idle. Without the equalizer the load would probably be



C & N. W Ry.
RAIL LIFT FOR
KINNICKINNICK DRAW BRIDGE (No 1551)
MILWAUKEE DIVISION
Chief Engineer's Office, Chicago Jan 31, '99
Drawing No 2513
4 Stools required
Stand angle bars for 90" rail
4 Hinge Rails Required
2 Right and 2 Left
4 Fixed Rails Req'd
2 Hand Levers (wrought iron)
16 Detector Arms "C" (Malleable cast iron)
4 Counterweight Arms (wrought iron)
Make 24 Cast Iron Counterweights
8 Cast Iron Cams Required.
16 Rail Guides Required
Mark "E"
56 Boat Pls Req'd
8 Cast Iron Boxes req'd.
Mark "B"
4 Cast Iron Boxes - Mark "A"
Material furnished by Ry Co
Diagram showing lengths of rails on Bridge
Section A-A
Bot View of Angle Bars
C.L. of Truss
C.L. of Track


LACED WEB MEMBERS
Note Some of the chord sections have been rearranged See Bridge Co's plans Sheet No 33
HALF END VIEW
HALF CENTER SECTION
SPECIFITIONS
LOADING
LIVE LOAD 2-131.5 TON ENGS + 4400 LBS.
DEAD - 4600 LBS PER FT BRIDGE
RIVETS ETC.
ALL RIVETS ⅞" DIAM. EXCEPT IN BRACING ¾ DIAM.
ALL RIVET HOLES PUNCHED ⅛ SMALL & REAMED
ENTIRE CENTER FROM LOWER TREAD TO
CROSS GIRDERS INC ASSEMBLED IN SHOP
HOLES REAMED & PIECES MATCH MARKED
MATERIAL
SOFT STEEL
ALL STRUCTURAL MATERIAL
CAST STEEL
CONED WHEELS & LOWER CENTER DISC
FORGED STEEL
TOP & BOT TREAD PLATES
CAST IRON
TOP & BOT TREADS - END BEARINGS & CENTER CASTING
PHOSPHOR BRONZE
UPPER CENTER DISK
— C. & N. W. RY. —
Stress Sheet of
Swing Bridge over Kinnickinnic River
Chief Engineers Office - Chicago - Sept 1898
Correct W. H. Finley Approved
Engr Bridges
Chief Engr
STRINGER - 26' B TO B. L^S
EACH FL 2-5×3½×⅝ L
WEB 1-24¾×⅜ PL
END SHEAR 41300 LBS
FLOORBEAM - 48' B TO B L^S
EACH FL 2-6×6×¾ L - 1-14×⅝ PL 16.0 - 1-14×⅝ PL - 24.0
WEB 47¾×½ PL AT ENDS - 47¾×⅜ PL AT CENTER
END SHEAR 135200 LBS.
END FLOORBEAM - 48' B TO B L^S
EACH FL - 2-8×8×⅞ L - 2-8×½ PL 20.5
WEB 2-47¾×⅜ PL.
END SHEAR - 122400 LBS.
GIRDERS A & B 57¼ B TO B L^S
EA FL 2-8×8×⅞ L
WEB 1-57½×½ PL.
END SHEAR - 124800
GIRDER C - 55' B TO B L^S
EACH FL. 2-6×6×⅝ L's
WEB - 1-54¾×½ PL.
END SHEAR 124400 LBS
GIRDER D - 55' B TO B L^S
EA FL 2-6×6×¾ L^S - 1-14×¾ PL 26.0
WEB - 1-54¾×½ PL
END SHEAR 91000 LBS.
GIRDER E - 50' B TO B L^S
EA FL. 2-4×4×⅝ L^S
WEB 1-49¾×⅜ PL.
END SHEAR 32500 LBS
GIRDER "F" 61' B TO B L^S
EA FL. 2-5×3½×½ L
WEB - 1-60¾×⅜ PL
END SHEAR 32500 LBS.
Drawing No 2442

all borne by one pinion, and you might just as well have but the one pinion, and not the two. I do not see how you could expect to have two pinions do the work without the equalizer; that is, in fact, the function of the equalizer, that the work should be distributed between the two pinions.

Mr. G. P. Nichols—My idea, based on observation and experience, is that if the rack and pinion are made and fitted with a reasonable amount of care, the pinion and whole train of gearing brought to a bearing, and then the key seat in the shaft for one of the bevel pinions or any of the gears be cut, results will be obtained which are wholly satisfactory. I have used this method on quite a number of bridges, the largest one being the Rush Street bridge, Chicago, which has now been running in this manner for about ten years and I have never heard any adverse criticism on its workings. Of course, this method should only be used where the cross shaft is of some considerable length and not where the two vertical shafts are very close together, which would eliminate the possibility of the necessary amount of torsion. The equalizer in itself is somewhat complicated on account of the introduction of additional bearings, pinions, etc., and every such complication, on a class of machinery which at the best receives very little attention, is to my mind a dangerous element and the simpler the machinery can be made the more satisfactory will be the results.

Mr. Finley—There is nothing complicated about the equalizer; it is about as simple a piece of machinery as you can put on the drawbridge.

Mr. Reichmann—While in Milwaukee the other day I spent a few spare moments in looking over the city bridges which are being operated by electricity. These bridges are small and light, and their gearing is cast and very crude and has no equalizers. I saw one of the bridges had broken a pinion shaft fully three and one-half inches in diameter, which undoubtedly was due to the fact that they were running the bridge without an equalizer, for I know we are operating bridges fully twice as heavy as that with the same size shafts, and they do not break.

Mr. Modjeski—It would seem to me that it would be rather poor policy to make that shaft light; it is one of the important parts of the machinery, and when it is made light it is subject to fatigue under reversal of stresses, and is therefore liable to give way, so that it should be made one of the strongest parts of the whole machinery.

Mr. Strobel—I would like to ask Mr. Bainbridge whether he can give us the reason for adopting a gasoline engine for that bridge, rather than the more customary electric motor. And further, whether he can give us any examples showing that the riveted lattice type of bridge will stand overload better than the pin-connected bridge, as he claims.

Mr. Bainbridge—As regards the relative advantage of gasoline engines and electricity, I think no one would use the gasoline engine where electricity was available. In this case we did not have elec-

tricity available. As regards the failure of pin-bridges from overloading, I have not in mind any specific instances just now, but the failures of pin-bridges that have occurred have been largely due to the excessive vibrations in the bridges due to the wearing of the pin. I have never seen an old pin bridge taken down but that the pins were worn from 1-16th inch to deeper, and in the case of those pin bridges from fifteen to twenty years old, when trains run over them they shake so as to frighten you ; a riveted truss does not. It may be entirely in the mind, it may be the pin bridge is as safe or safer, but it does not give that impression ; those old pin bridges shake and the counters break also—there are numberless instances of counters breaking. Now, with a few bad breaks on a bridge, any man who has anything to do with the bridge is frightened at it, and he immediately concludes that the bridge ought not to be there. On riveted latticed bridges there is almost no part that can break until the whole structure is ready to come down. An exception to that, however, is some badly designed floor beams. On many old riveted lattice bridges the floor beams were cut out about one-half at the ends so that they could bear on the bottom chord. These floor beams frequently break.

Mr. Strobel—I know of no pin connected bridge that failed by reason of the breakage of a pin. The vibration usually causes wear somewhere, but it is generally light members, such as counters and lateral rods, that make trouble. Where the parts connected to a pin are large, there is usually no wear. It seems to me to be an advantage if you can tell that a bridge is hard pressed. I think that these riveted bridges that are overloaded without anyone knowing that they are overloaded, are a greater danger than those bridges which indicate that they are hard used.

Mr. Finley—To carry Mr. Strobel's argument out to its logical conclusion, the safest type of bridge would be the Howe truss bridge, much more so than the pin connected or any other bridge, because it would give you more ample warning of danger ahead. I have taken down a number of pin bridges and I have found in almost all cases that the parts were well worn, and it is not so much that, as the moral effect it has. Taking a pin bridge where the pins are moving, you will always find a rust streak from the pin. I do not think there is any danger of a bridge being overloaded and a collapse taking place before those in charge find out the dangerous conditions.

Mr. Reichmann—The old lattice bridges as a rule have heavier counters than the pin bridges, because the minimum size angle that it is practicable to use give an excess of material in the center diagonals. I think if the counters are made properly they will not break. Of course we all know that an increased live load acting on the bridge will affect the counters more than any other member. In all well designed bridges this is properly considered.

Mr. Finley—The counters in a lattice bridge naturally are made larger than the counters of the pin bridge ; taking up one kind of

stress, that is simply a necessity in the case. Speaking of this subject of the pin and the lattice bridge, I am rather amused at the present tendency. Those who object to the lattice bridge will build a pin bridge and rivet in their posts and hip joints. They rivet those up and they have a bridge that is neither fish, flesh nor good red herring.

Mr. Bainbridge—I think the principal objections which have been urged against the lattice bridge are that it is impossible to secure good field riveting, and that in riveted joints carrying heavy strains, you can not depend upon the stress being carried by the whole number of rivets there. This objection is met by limiting the span and dividing up the systems so that the strains carried by each system are as small as possible. I think there should be a limit to the span so that the question of taking care of heavy stresses in single line should be avoided.

Mr. Strobel—What I was trying to find out from Mr. Bainbridge was what evidence there was for his statement that you can overload a lattice bridge better than you can a pin connected bridge. Of course the moral effect on those operating these bridges is quite a thing apart. Then, too, I was trying to find out whether there was any evidence of failure of the pin connected bridge by reason of the pins wearing. There have been many failures of bridges of all kinds, but almost invariably they have failed because the proportioning was bad from the start. I should prefer, if there are no disadvantages, to always have a structure that shows its weakness, if that could be.

Mr. Finley—A railroad company looks upon a bridge as a tool constructed for its use, and it wants one that will, for the least amount of money, render the best service. I am satisfied that a pin bridge would not have stood the damage and abuse that the bridge at Fond du Lac endured, or the one at Daggett, where carloads of logs passed over, ripping out web members. That is the standpoint of a railroad company in the matter of bridges; it wants a bridge that will give it a fair amount of security under the extraordinary conditions that are likely to occur.

Mr. Reichmann—I would like to ask Mr. Bainbridge whether he uses the multiple system of intersection to keep the stresses small in the individual members and thus avoid so many rivets in one connection.

Mr. Bainbridge—That is the principal reason.

Mr. Reichmann—I think theoretically there are a good many objections to the multiple system. For instance, you tie the tension and compression members, which are both acting at the same time, together. There is no question that that is not right theoretically, while practically it works all right.

Mr. Bainbridge—There is another objection to the multiple system in that the panel points are about half the distance between the car wheels. As a general thing, a bridge will be about 28 feet deep and the inclination of the laterals will be about 45 degrees; the dis-

tance of car wheels is generally about 28 feet, so that in passing over the bridge the wheels pass from one system to the other. That is an objection to the multiple system.

M. W. Trumbull—What is the relative length of time it takes to put in place a riveted bridge and a pin connected bridge, both being fixed types?

Mr. Bainbridge—Well, of course the conditions will govern a great deal in that. There is no doubt that a pin bridge can be erected in a much shorter time than a riveted bridge. In this case we were about six weeks and a half in erecting this bridge, from the time we started. A pin bridge could probably, with the same force, have been put up in three weeks and a half.

Mr. Strobel—It might be well, while speaking of this subject, to call attention to one feature. These riveted lattice bridges with short panels are exceedingly indeterminate, as we well know, in regard to the actual stresses in the members, so much so that by actual test of completed bridges it has been found that in certain cases some members have had compression that should have had tension, etc. On this account there has been a decided tendency in countries that use only riveted bridges to get away from the lattice bridge and use trusses with a single system of triangulation. Because of the large secondary stresses and because of the uncertainty of the stresses you properly ought to proportion your lattice bridge much more liberally than you do a bridge with a single system of triangulation.

Mr. Bainbridge—I believe there is no more uncertainty about the stresses in a lattice bridge than in a pin bridge. In the case of a pin bridge in which the pins are worn, the passage of a train over the bridge will in many of the web members cause the bearing surface to change from one side of the pin to the opposite side, producing shock in the member. Also it is a common occurrence in pin spans to find two tie bars side by side, one of which continues loose during the passage of a train while the other is taut at all times. If a lattice bridge is erected with ordinary care there should be no great uncertainty as to stresses. Of course, if the holes fit badly and much drifting is done there will be uncertainty. We require that where rivet holes do not match they shall be reamed in the field.

Mr. Reichmann—I think a good many fine mathematical points come in here. In figuring the moments on a pin we take the distance center to center of bearings, so the more liberally we figure our pin bearings the greater the pin moment figures. We would get results more nearly correct if we figured the moments for a uniformly distributed load over the bearings. This is one of the assumptions made in figuring pins, but there can be no objection to it since it errs on the side of safety. As far as the motion of the pins is concerned, it can only be produced by members having a reversal of stress, which, in ordinary truss bridges, would be the stiff counters.

Mr. Bainbridge—There will be two or three posts on each side of the center where there must be motion up and down; that is, pro-

viding counters are needed, there is likely to be motion in the post there.

Mr. Condron—I would like to inquire what the specifications in reference to metal and punching and reaming are.

Mr. Bainbridge—Mr. Finley is more familiar with that than I am.

Mr. Finley—They are built under the standard specifications of the C. & N. W. Railway; they all call for punching and reaming on lattice bridges. I will take the bridge that Mr. Bainbridge just described: The great point in favor of the pin bridges is the fact that they can be built without being first assembled. I believe the practice is in Europe, or at least in England, to assemble those riveted bridges in the shops before they are sent out. Here that is not necessary. This particular bridge was not even laid out on the floor; the templates were made out on the bench, and I think the bridge went together remarkably well; we had no trouble from the mismatching of holes, and did not require drifting, or anything of that sort to make them come together.

The Chair—Mr. Bainbridge, what method of riveting was used, hand riveting or pneumatic?

Mr. Bainbridge—Hand riveting entirely.

The Chair—Would not the pneumatic methods better the construction, if that could be applied to a case of that kind?

Mr. Bainbridge—Why, yes, I think as a whole that either the pneumatic hammer or pneumatic riveter is better than hand riveting.

The Chair—It approaches close to the shop practice, does it not?

Mr. Bainbridge—Yes.

Mr. Warder—I would like to make an inquiry in regard to the increased cost of the riveted lattice bridge over the pin bridge. Is it due to the greater weight, or to the shape of the bridge, or the kind of work involved?

Mr. Bainbridge—The difference is due almost entirely to the weight. But there is some increased expense in erection—I think possibly two dollars a ton increase in the cost of erection.

Mr. Finley—There is very little difference in the cost per pound erected in place.

Mr. Modjeski—The strength of pins was mentioned here. Some might be interested to hear that in the Rock Island bridge, where we took down the old bridge, some of the pins 3½ inches in diameter, if figured theoretically according to the usual method, were strained to about 180,000 pounds per square inch fiber stress.

Mr. Finley—That bears out my point of the uncertainty of pin bridges theoretically.

Mr. Bainbridge—The whole question in these pins which figure up 180,000 pounds per square inch—I have seen a number of those cases—is that the members connected to the pins in the same direction do not receive their strain uniformly; that is the whole point, and it shows, unless the pins are made very large, to allow exceedingly small deflections, that you can not depend on the stress being

equally distributed over more than two members attached to the same pin.

Mr. Modjeski—I would add that among all these pins there was not a single one where one could detect any bend after it was taken out, no wear, nor any bending at all. I have figured a little closer, using different assumptions, on the actual strain per square inch that these pins would be subjected to, and I figured about 50,000 pounds.

Mr. Finley—There is a wide discrepancy between theory and actual results in pin bridges.

Mr. Strobel—The material of a bridge is never uniformly strained in any kind of bridge, riveted or pin-connected. Though we assume for purposes of calculation that there is a uniform distribution of stress over a cross section, yet we know that there never is and that we are bound to have considerable variations from that. The point I was making a little while ago was that in a single system of triangulation there was no assumption necessary to determine the stress in the truss members. For a multiple system, calculating by static methods, you assume each system will act independently of the other, which is only approximately true. After you have calculated the stresses in the different truss members, then to calculate details is another thing, and whether you get the stresses into your members better by means of riveted or pin connections is a subject that, to enter upon here, would be going too far. You can design both the pin connected bridge and the riveted bridge badly, and you can arrange so that your distribution will be very unequal. It seems to me that we ought not to lay too much stress upon these details.

Mr. Finley—The details are the most important points of the bridge; they are the points that always fail; the failure generally occurs near some attachment or connection.

Mr. Bainbridge—Some years ago I examined a bridge that was thoroughly suited for the traffic at that time, except that the pins were considered weak. The parties in charge concluded then to put false work under the spans, block them up and replace the pins. They of course had to replace them with pins of the same size, but they managed to secure for their pins a metal, I think it was gun metal, which, with all the customary requirements of elongation and reduction of area, gave an ultimate stress of about, I think, 140,000 pounds per square inch. It seems very large, but, as I remember, that was about it. I do not consider that these people had improved their bridge in the slightest; there was no danger of the pins breaking, I think that has been settled for all time, but there was just as much probability of their fancy gun metal bending and allowing a bad distribution of stress in the bars as with the old pins.

Mr. Finley—We seem to have strayed away from the drawbridge entirely.

Mr. Reichmann—I want to ask Mr. Bainbridge whether he figured on the center casting so that he would have a load on the center pin?

Mr. Bainbridge—Yes, we would like to have a load on the center, so that the drum will not vary in position on the wheels. If there is

a considerable load there, it is certain that the center will be held in place, also the fact that there is a load on the center reduces the force required to turn considerably. We turned the bridge before we transferred the load to the center, and afterwards, and the difference was quite appreciable.

Mr. Modjeski—Speaking of centers and discs, I would like to ask Mr. Bainbridge whether he has ever had experience with using hardened steel discs, in place of phosphor bronze? I understand this has been used lately to good advantage, and has given very good results.

Mr. Bainbridge—You mean the use of hard steel upon hard steel?

Mr. Modjeski—Yes.

Mr. Bainbridge—No, it is something that I must confess I do not know anything about. But I will say that the people who manufacture phosphor bronze claim for it that the small frictional resistance of phosphor bronze upon hard steel is due to the granules of lead in the phosphor bronze. I do not know just how much there is in it, but it seems quite reasonable. There is a certain amount of lead in a phosphor bronze, and they claim that the plate slides on the lead granules.

The Chair—Are there any further questions, or is there any further discussion on the paper?

Mr. Bley—What is the material of it, both steel and phosphor bronze?

Mr. Bainbridge—The upper plate, the turning plate, is phosphor bronze, the lower plate is a hard steel plate.

Mr. Bley—Hardened, and with the surface ground after it is hardened?

Mr. Bainbridge—It has the polished surface.

Mr. Bley—Was that made out of tool steel, or ordinary machinery steel?

Mr. Bainbridge—I think it is tool steel; I am not quite sure about that.

Mr. Finley—We use simple hardened machinery steel.

Mr. Bley—I would like to ask what sort of friction drive was used, what sort of an arrangement did you have to transmit motion?

Mr. Bainbridge—They are simple cone frictions, with wood contact.

Mr. Bley—Each cone is perfectly solid when it is put in place?

Mr. Bainbridge—When it is forced in, yes.

Mr. Bley—Was the bearing on the side of the wood or end of the grain?

Mr. Bainbridge—The bearing is on the side of the wood. The wood is maple.

Mr. Bley—You get the drive by forcing one cone on one side into the other?

Mr. Bainbridge—Yes.

Mr. Modjeski—You made no experiments as to the percentage of friction to the weight of the bridge?

Mr. Bainbridge—No, we have not.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

INCRUSTATION OF WATER MAINS AT TORQUAY AND ELSEWHERE.

(*Abstracted from Proceedings of the Institute of Mechanical Engineers, October, 1899.*)

The water supply for Torquay is from the Dartmoor hills and is a soft up-land water from a granitic formation collected in two large storage reservoirs, and then piped to Torquay. One of these mains is 10 inches diameter, reduced on the line to 9 inches, and further on to 8 inches. It is 14 miles long and was laid in 1858, and the mains had no protective coating. In 8 years' service incrustation had developed to such an extent as to reduce the full discharge capacity to less than one half. About 1866 a scraper was designed and sent through the main by the pressure of water behind it. Subsequently the form and construction of the original scraper was modified. As now used, the scraper measures 3 ft. 8 inches long, and consists of a first part, of a framework carrying knives held in place by springs. The after part consists of two brass discs about one inch less diameter than the pipe, with a leather flange fitting the interior of the pipe. A universal joint between the front and rear portions renders the machine flexible, to more readily adjust itself to the pipe. As the leather at the discs is a little larger than the brass discs, and the internal area of the pipe, they make an almost tight joint in the pipe so the pressure of the water behind forces the scraper forward. Two discs are used, spaced about 1 ft. apart, to enable the scraper to pass any side branches, as there will always be one or the other of the discs filling the full dimensions of the pipe and subject to the pressure of the water behind it. The steel knives are four in number and are held in position by spiral springs. At the front end or nose of the scraper there are four flat elastic spring bars bending backward to serve as guides, to carry most of the weight of the scraper and keep it concentric with the pipe. The four knives are of a V shape, with the sharp point forward, each one measuring a little over one-quarter of the inner circumference of the pipe, and are placed in pairs diametrically opposite, one pair being somewhat in advance of the other pair. The force of the water to drive the

scraper forward has been found to be about 5 lbs. per square inch. For smaller pipes this would need to be increased, say to 8½ lbs. per square inch for 6-inch pipes.

The author gives a table showing the benefit of scraping out incrustation, and incidentally removing many foreign bodies from the pipe line, as lead, tools, stones, etc. The table shows the effect of scraping pipes 18 inches diameter down to 6 inches diameter and fourteen miles long and less. The increase in delivery after scraping ranged from 23 per cent to 56 per cent, and more. At Torquay the cost of scraping was as low as 1-5 cent per yard; at other places as high as 37 cents per yard. In general the cost per yard was less the longer the main to be cleaned. The author dwelt upon the desirability of having suitable washouts and hatch boxes, or openings, to get access to the interior of the main. In most of the other cases noted, besides that of Torquay, the incrustations seemed to be nodules or tubercles of oxide of iron, and these naturally occurred to a greater extent in the mains which had no protective coating. Moreover, a greater force was needed to remove them than in the case with coated pipes. But the coating of the water main with Dr. Angus Smith's coating was not a complete preservation from these ferruginous incrustations. The time required to send the scraper through the new 14-inch main at Torquay, which pipe had been treated by Dr. Angus Smith's process, was three hours for the first section of 8 miles, and again three hours for the second section of 6 miles. The hydraulic gradient in the Torquay main is higher than in some places in this country, being about 1 ft. in 264 ft., and giving a velocity in the new 10-inch coated main of about 4 ft. per second. The "scrapings" or "rust" removed from the pipe, upon analysis showed 49 per cent of iron, presumably from the pipe, and 51 per cent of deposited matter, made up of lime, silica, organic matter, etc. The author lays down the liability to rust, thus: if cast iron is taken at 100, then wrought iron will be 129 and steel will be 133.

The soft water from upland reservoirs of a granitic formation and full of "sparkle" or air, and perhaps also some acid from peat or bog formation, have a greater rusting action on the iron pipes, even if coated, than some well or spring waters containing lime and other alkalis.

The discussion of the paper brought out the subject of coating pipes to protect them from the rust. It is desirable that the protective coating be put on the pipes as soon after they are cast and cleaned as practicable, and before any incipient rust has begun from exposure to the weather. It is also very desirable that the pipes be heated to a moderate temperature, say about 500° to 600° Fah. and then dipped in the bath of an asphaltic compound and allowed to remain submerged long enough for the coating to become fully adherent to the iron; then slowly withdraw the pipes and incline them so all surplus coating will drain off. In some cases the use of steam pipes at the bottom of the tank holding the coating

material was found very desirable, thereby maintaining the coating material warm and fluid, whatever may be the weather. The composition of the coating material should be carefully noted, to make sure that by continual heating and use the more liquid parts be not evaporated, rendering the coating hard and brittle when cold, and thus liable to chip and scale. The addition of linseed oil to the coating material is recommended to make the compound more tough and less liable to chip and scale.

There is this to be said about scraping the interior of water mains: If the main has been coated the use of the scraper with steel knives is destructive to the coating, and, further, the formation of the nodules or tubercules inside the pipe is more rapid after the first scraping than before, so if scraping be once begun, it must be repeated at more frequent intervals in the future, to keep the pipes clean.

It can be readily seen that incrustations averaging ⅛ inch thick on the interior of a 10-inch water main will reduce the area of flow to a greater degree than an incrustation two or three times as thick on the inside of a larger main, say of 36-inch diameter.

The "Deacon" machine was brought out in the discussion. This, instead of being a scraper such as has been described was a brush made of whalebone bristles. This was designed to use in the "Vyrnwy" water main, 42 inches in diameter, and 13 miles long, for the water supply of Liverpool. A hollow spindle of tubing was used, with a wooden disc at one end, provided with leather flanges fitting the interior of the pipe. This disc was not solid, but built up with arms between a central hub and the rim. These openings amounted to 297 square inches or 21 per cent of the whole area of the 42-inch main. On the other end of the central spindle are mounted two solid wooden discs, each about 3 ft. diameter and 1 ft. thick, and free to revolve on the central spindle as an axis. The 3-inch space all about these discs is partially filled with the brushes made of whalebone bristles, each about 1-20 of an inch square. These brushes are each about 13 inches long by 1 inch wide and are arranged about the wooden discs on the lines of helices or spirals, but with this difference, that the set of brushes on one disc slope in an opposite direction to those of the other disc. The effect of these sloping brushes between the solid center and the interior of the pipe is to give the discs a rotary motion due to the reactive pressure of the water passing by them, for the current of water in the pipe is more rapid than the forward movement of the whole machine, which is held back by the friction of the tail piece with its leather packing pressing against the interior of the pipe. The effect of the action of this pipe cleaner is to give the interior of the pipe a brushing, first in one direction by the first disc, and then in the opposite direction by the second disc, and also to have a greatly augmented speed of flow of the water due to the contracted space between the brushes. At the same time, there is a comparatively slow forward movement of the whole machine.

Trial and experiment showed the best velocity of the machine and water to be a current of one mile an hour for the water in the main and a movement of the machine forward of only 1-3 mile per hour, as retarded by the friction of the tail piece leathers in the pipe, yet the velocity of the water past the brush discs was as high as 10 miles per hour or 15 ft. per second. The sluice cocks, 12 inches diameter, and spaced a mile or two apart, were opened only part way, but permitted the washing out of the incrustation that had been removed by the machine. The action of the brushes did not damage the asphaltic lining of the pipes and the flow of water was increased about 1-3—from 12 to 13 million gallons per day before cleaning out, to 16 or 17 million gallons per day, after cleaning.

In conclusion, it should be noted that whereas the earlier form of scrapers in passing through the water mains gave audible evidence of its passage, and it could be followed and located as long as it was moving, yet with the later form, with the brushes, there was no noticeable sound, until a "sounder" was attached. This consisted of a series of "trips," arranged about the revolving heads, which actuated hammers that hit the hollow spindle, giving forth a sound that could be heard above ground. The varying rapidity of these sounds indicated the movement of the revolving brushes and whether the whole machine was moving forward or lodged in the pipe.

W.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING, MARCH 7, 1900

A regular meeting (the 418th) of the Society, was held in its hall on Wednesday evening, the 7th March, 1900, President Ambrose V. Powell in the chair.

The report of the Board of Direction was called for and the Secretary read the following: At a meeting of the Board of Direction today the following persons were declared elected as Active Members: Jas. A. Seddon, A. M. Haynes, Henry I. Randolph, E. H. Heilbronn, J. J. Harding, Chas. H. Davis.

As Associates, Hugh M. Wilson.

As Juniors, Louis H. Flanders.

Transferred from Junior to grade of Active Members: Theodore J. Klossowski, M. E. Thomas, Henry H. Lotter.

The following applications were received and referred to the Membership Committee: For Active Membership from Wallis R. Sanborn, Chas. H. Cartlidge, J. T. Canfield, Geo. Cole. For Junior Membership from Merle D. Hill, B. F. Beckman, W. H. North, T. R. Cummins. For Transfer from Junior to Active Membership, W. M. Christie. Associate to Active Membership, G. J. Johnson.

There being no further business the chair announced the subject of the paper of the evening: "Apparent Failure of Railway Interlocking Plants to give Ample Protection to Trains," by Carl E. Davis, M. W. S. E.

In the absence of the author the Secretary read the paper. At the conclusion of the reading the chair stated that discussion was in order. Mr. B. C. Rowell arose and said he had prepared a written reply to the paper, which he proceeded to read, and which appears in this issue. of the Journal.

A general discussion of the subject followed, in which the following gentlemen took part: Mr. S. S. Neff, Superintendent of the Union Elevated Loop; Mr. Rowell, the Chair, E. E. R. Tratman, Mr. de Berard, A. Reichmann.

Mr. W. T. Keating made a motion that the matter be printed and distributed to the members and have the subject up for discussion at some early future meeting, which was duly seconded. After brief discussion of the motion, it was decided to leave the date for the discussion to the decision of the Chair. A member suggested that when the discussion takes place Mr. Rowell illustrate the Rowell-Potter device with lantern slides.

Mr. Rowell was invited to comply with the suggestion, and he accepted the invitation.

Mr. T. L. Condron stated that Mr. Neff would be glad to give an exhibition of the safety stop device in use on the Union Loop to such members as would be inclined to go on a trip around the elevated loop. The Chair thought this proffered opportunity would be a desirable supplement to the meeting, as it would give all interested members a chance to see and discuss the actual working on the ground, and give a clearer idea of the subject, and accepted for the Society Mr. Neff's invitation.

The meeting adjourned.

SPECIAL MEETING, MARCH 21, 1900.

A special meeting (the 419th) of the Society was held in its hall on Wednesday evening, 21st March, 1900. President Ambrose V. Powell in the Chair, and 42 members and guests present.

There being no business to transact at this meeting, the Chair presented Mr. Octave Chanute, who read a paper on "Preservative Treatment of Timber." Mr. Chanute has devoted a vast deal of time and careful study to this subject, and the paper is of exceptional value. In connection with the paper Mr. Chanute presented a translation of the specifications of the German treatment of ties.

The paper and German specifications appear in another place in this issue of the Journal. The paper called forth an extended and interesting discussion, participated in by Messrs. L. E. Cooley, Chas. L. Strobel, F. H. Bainbridge, J. H. Warder, L. H. Flanders, S. G. Artingstall, E. E. R. Tratman, W. H. Finley, W. W. Curtis, Prof. W. D. Pence, F. K. Vial, the Chair and Mr. Chanute.

The meeting adjourned.

REGULAR MEETING, 4TH APRIL, 1900

A regular meeting (the 420th) of the Society was held in its Hall on Wednesday evening 4th April, 1900. President Ambrose V. Powell in the Chair.

The minutes of the previous meeting were read and approved.

REPORT OF THE BOARD OF DIRECTION.

At a Board of Direction meeting held on the 21st March, 1900, the following persons were declared elected: As Active Members, Wallis R. Sanborn, Charles H. Cartlidge, John T. Canfield, Geo. Cole; as Junior Member, Merle D. Hill, B. F. Beckman, W. H. North, Thos. R. Cummins; transferred from Junior to grade of Active Member, W. M. Christie; from Associate to Active Member, G. J. Johnson.

Application received from Clinton McDonald for Junior membership, referred to the Membership Committee.

Before the presentation of the paper of the evening, Mr. Geo. P. Nichols stated that Mr. S. S. Neff, Superintendent of the Union Loop, had invited the Society to take a trip over the Loop that afternoon, and Mr. H. M. Brinckerhoff, Asst. General Manager of the Metropolitan Elevated, had placed a train at the disposal of the Society, to give the members an opportunity to see the working of the safety appliances of the elevated road; that the trip was very enjoyable, and the Society having been the recipients of these courtesies, it seemed fitting that a vote of thanks should be tendered to these gentlemen, and to the companies they represent. He moved that this action be taken. The motion was carried by a unanimous vote.

The Chair then announced the paper for the evening, by Mr. Francis H. Bainbridge, on the "Rebuilding of the Kinnickinnic River Swing Bridge on the Chicago & Northwestern Ry. at Milwaukee, Wis." Mr. Bainbridge proceeded with his reading, illustrating various features with lantern slides, and giving explanations of each view as it was projected on the screen. The paper developed an animated discussion in which Messrs. G. P. Nichols, F. H. Bainbridge, W. H. Finley, A. Reichmann, Ralph Modjeski, C. L. Strobel, the Chair, J. C. Bley and M. W. Trumbull took part.

The meeting then adjourned.

NELSON L. LITTEN,
Secretary

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchanges and in completing valuable volumes of our files.

Since the last issue of the Journal we have received the following gifts from the donors named:

Bureau of Mines, Ontario, Report of, Vol. VIII, P. 2nd.
Fieldens Magazine Co., Fieldens Magazine, Industrial Progress, London.
Colorado Scientific Society, Notes on Mining and Smelting in the State of Durango, Mex.
J. H. Lary, C. E., The Public Roads of Linn County.
Iowa Society of Engrs. and Surveyors, Report of the Good Roads Committee.
Hon. J. R. Mann, M. C., Report of the Commissioner of Navigation, 1885, 1886-9, 1892-3-4-5-6-7-8-9.
Cement and Engineering News, "How to Use Portland Cement."
Dept. of Interior, Water Supply and Irrigation Papers of the U. S. Geological Survey, No. 32.
Interstate Commerce Com. Preliminary Report of the Income Account of Railways in the U. S. year ending June 30, 1898.
American Chemical Society, Report of the Committee on Coal Analysis.
E. Lee Heidenreich, Monier Construction.
Hon. J. R. Mann, Annual Report American Historical Asso. 1890-1-7-8.
Mr. Desmond Fitzgerald, Water Supply and Work of Metropolitan Water District, 1900: Report of the Topographical Survey Commissioners 1899: A Short Description of the Boston Water Works: Annual Report City Engineer Boston years 1880, 1881, 1882, 1883, 1885, 1887, 1888, 1889, 1890,1891, 1897, 1898.
Hon. J. R. Mann, Proposed Power Canal of Michigan Lake Superior Power Co: American Trans-Pacific Cable: Pacific Cable.
Regulation of the Level of Lake Erie.
Am. Soc. C. E., Constitution and List of Members, February, 1900.
Am. Institute of Architects, Proceedings, 33rd Annual Convention, 1899.
E. E. R. Tratman, The Wilder Gravity Filter,
Witham New Outfall Channel and Improvement Works,
New York Railroad Club, Proceedings May 20, 1897.
Launhardt Formula and Railroad Bridge Specifications by Henry B. Seaman.
Proceedings Connecticut Civil Engineers and Surveyors Association 1899.
Painting Metal Bridges, by Wm. B. MacKenzie.
Note on Unfreezable Dynamite.
Proceedings of 14th Annual Convention of Road Masters' Association, 1896.
"Steel Rails," by Christie P. Sandberg.

U. S. Dept. of Agriculture, Forestry Division, Bulletins No. 1 and 7.
Am. Soc. C. E., The Preservation of Timber, Report of Com. on Die Hasselmann'sche Impragnier-Methode.
Am. Inst. of Elec. Engrs., Transactions Vol. V, No. 2, 3, 4, 5, 7, 8, 9;
Vol. VI, complete;
Vol. VIII, No. 12, Vol. IX, No. 2.
A. Noble, Regulation of the Level of Lake Erie.
Chief of Engineers, 10 packages of House Documents relating to Engineering.
Kansas, Sec'y of State, Report Board of Irrigation Survey and Experiment, 1895-6.
6th Biennial Report, Com. of Forestry and Irrigation, June 30, 1898.
Geo. W. Rafter, On Water Supply and Storage, 11 pamphlets.
On the Theory of Concrete, by G. W. Rafter.
Report on Concrete Tests, by G. W. Rafter.
Report on Movable Bridges as used in Europe by G. W. R.
Report on High Masonry Dams in Europe, by G. W. R.
The Indian River Dam, by G. W. Rafter and others.
9 Miscellaneous pamphlets.
Government, U. S. Coast and Geodetic Survey, 67th Annual Report, 1897-8.
Patent Office, Great Britain, Patents for Inventions, Period A. D. 1893-96.
Institution of Mechanical Engrs., List of Members, February, 1900.
Nova Scotian Institute of Science, Proceedings and Transactions, Session 1898-99.

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XCII.

PARKS AND BOULEVARDS.

By A. C. Schrader, M. W. S. E.

Read May 2, 1900.

The proper construction and correct maintenance of a park or boulevard system undoubtedly does much toward creating civic pride, as well as public spirit and interest in the welfare of a city or municipality. A stranger visiting a city frequently wishes to see the parks and boulevards, as well as the public buildings, and these improvements often serve as a fair index of the public spirit of its citizens, modified perhaps by the city's commercial prosperity and importance. No further arguments will here be made in favor of the construction of parks and boulevards, as they are too numerous and well known to require mention. Their existence in many of our cities is proof of their desirability, but their extent and effectiveness are too frequently limited by lack of foresight or funds.

In order to avoid an extravagant outlay, the proposed land should be secured as early as possible, but, since a city's growth and importance cannot always be predetermined, the selection of grounds is frequently delayed. The final location and adoption of park grounds is therefore not infrequently determined by other considerations than that of adaptability, and is usually incident to, and dependent upon, the growth and commercial importance of the city.

The work of making a park of the lands selected usually devolves upon the engineer and the landscape gardener, working in harmony and with the same end in view, namely, to emphasize and render more attractive any desirable existing features of the chosen grounds, and to obliterate the undesirable; to prepare a well matured plan for the improvement of the whole park as a unit, and

after its adoption to adhere to the lines laid down, and discourage as far as possible the frequent attempts of succeeding boards of control to materially change the plan. The importance of following a complete and well matured plan cannot be overestimated, and especially is this true when the controlling board is subject to changes in its personnel, and therefore a change of ideas as to desired improvements. As the construction or final completion of a park system is often extended over a number of years, the work of each year should be in close conformity with the adopted plan, and thus avoid the confusion and often the needless additional expenditure caused by a change of plans.

The working plans should accurately show the grade lines of all roadways and walks, and the conformation of ground or topography proposed, as well as the location and description of all water, sewer and electric light service, buildings, lakes and bridges. The planting plans should be drawn to the same scale as the grading plan, and should show the correct grouping of trees and shrubbery; and the numerous view lines to be preserved, and should be studied with reference to the grading plan to secure the proper landscape effects of trees, lawns, lakes, buildings, etc. An index to the planting plan should be prepared, which will closely define the kind and number of trees or shrubs, or both, in any group indicated in the plan; the work of preparing this properly belongs to the landscape gardener, and is important. The complete construction, however, of all the work, and the preparation of all detailed plans and specifications, come more particularly under the direction of the engineer of the park and boulevard system.

The duties of a park engineer, as some of our systems are managed today, are numerous, and he deserves not a little credit if his training and experience are sufficiently broad to enable him, without the assistance of specialists, to economically and comprehensively solve all problems presented. The broader his knowledge of civil mechanical and electrical engineering, architecture and landscape work, the greater the ease with which he may discharge his many duties, and the less the demand for the opinion or assistance of outside specialists. He is wise if he knows his limitations in this respect and leaves to specialists the particular parts of which he may have only a general knowledge.

The designing of park buildings should be under the direction of able architects, and be in harmony with the surroundings. As a rule the structures are not carried more than fifty to sixty feet in height, tall buildings being undesirable, as they may overtop the foliage line. Refectories are usually placed in the larger parks for the convenience and comfort of the public. Greenhouse construction should be carefully considered with reference to durability of

framework, roof outline and economical and effective heating apparatus. On account of the moisture in greenhouses, wood decays rapidly and, therefore, iron or steel, if kept well painted, is preferable. It is not desirable that work rooms or heated basements be placed under exhibit rooms, as this tends to make the air too dry in the exhibit rooms, unless an unusually heavy water-tight floor intervenes. All park buildings should be constructed with a view of having every side presentable; and sanitary regulations should be observed.

The impression which a visitor receives in viewing the parks, buildings, etc., should be one of restfulness or healthful recreation. The placing of monuments commemorative of historical persons or events in parks is evidently considered desirable by many park boards. The total absence of such monuments in some of our principal park systems may evidence a contrary opinion. The public squares frequently afford an advantageous location for such work, as may also prominent points along the main boulevards. The placing of such monuments, however, is usually an afterthought, and is seldom considered in the original plan.

A drinking fountain for horses, suitably designed and placed at an accessible point in the park roadway, usually forms an attractive feature. Drinking fountains for persons should be supplied at various points in the parks.

The original plan should contemplate a complete water and drainage service. For the purpose of watering the lawns, trees and floral displays economically and quickly it is desirable that the distributing pipe and lawn hydrants be so placed that all desired areas can be reached with about one hundred feet of hose, and so that a considerable number of sprayers may be in operation at the same time. In this manner one attendant can readily tend from twenty-five to thirty-five sprayers. The shorter length of hose also reduces the friction head losses and insures a greater discharge.

The drainage should adequately care for the rainfall on all roadways and walks, and such lawns as are apt to remain saturated for a considerable period of time after a heavy rainfall or during the summer months. For lawn drainage, farm tiling 3 to 6 inches in diameter is commonly used when a heavy clay subsoil exists. For the proper maintenance of the park roads, catch basins should be placed about 250 to 275 feet apart, depending upon the grades, and they should be placed so as to prevent the scouring action of heavy rainfall upon the roadway pavement.

The park roadways may vary considerably in width, depending somewhat on the size of the park. For the more probable lines of heavy travel, those most frequented, a width from 45 to 55 feet is ample in a large park, and from 35 to 40 feet in a smaller park. It

is desirable that the width of lawns in a smaller park be not too much dwarfed by the introduction of wide drives and walks, thus creating a disproportion of lawn and pavement areas. The principal entrances to the park, however, should be much wider, as a rule, than the other roadways, and these are frequently from 100 to 150 feet in width. Except in formal work they are laid out in curved lines; and their location should command the best view of the park. Crushed limestone, as well as bank gravel and crushed gravel are most commonly used in the construction of park roads, and, when heavy clay subsoil exists, cinders or slag may be used to good advantage as a subdrain, greatly facilitating the work on wet grounds. With the crushed limestone drive considerable dust is always present, unless well sprinkled, and the white glare in the sun is not pleasant to the eye, therefore a neutral tint is more desirable. Both defects can be partially remedied by using crushed granite and gravel for roadway finish, but at an advance in cost.

Paved gutters are not desirable, except where the roadway grades are steep, and it is desired that erosion, due to heavy rainfall, be checked thereby.

The walks and paths in a park may vary considerably in width, say from 6 to 16 feet, and their construction and maintenance should receive as much care as the roadways; ample drainage should also be provided, The surface should be smooth and unyielding, and should not become muddy or sticky, nor should the pebbles, if gravel is used, be so large as to be disagreeable to walk on. A fairly good walk may be laid on clay subsoil by using as a base from 9 to 12 inches of cinders, on which are placed from 1½ to 2 inches of screened binding gravel, and surfaced with a clean lake shore or river gravel, screened through a ⅜-inch mesh; it is desirable that the finishing gravel consist mainly of flat pebbles, rather than round ones. It is understood that rolling is necessary to compact the several layers of material.

The permanent improvement and easy maintenance of lawns is best secured by the liberal use of black soil, from 8 to 12 inches in thickness, depending upon the character of the soil. The same is true of tree planting, the depth of black soil required being from 2½ to 3½ feet, and of ample area to provide for the growth of the roots.

For the larger and more important roadway bridges the stone arch naturally suggests and admits of appropriate designing. Whether in heavy woodland or formal plantation, the particular locality and surroundings will indicate the use either of rough granite boulder facing or the carefully dressed stone facing and railing when the space is within the limits of the stone arch. For the longer spans, if iron must be used, the trusses should form

the arch outline, and no portion thereof should extend above the floor line; the structural iron work should be masked as far as practicable. For the minor bridges for paths, etc., the rustic type of woodwork frequently gives pleasing variety, but constant repairs are necessary. In general, it is deemed desirable that a bridge site be at least partially hidden by suitable tree or shrubbery planting.

The desirability of introducing speeding tracks for horses and for bicycle riders into parks, as park improvements, is questionable, and depends largely upon the manner in which they are conducted. While they are not particularly conducive to park embellishment, or to the landscape effects, they probably furnish a recreation ground to a considerable number of citizens, and then, too, all fast speeding may thus be removed from the boulevards and limited to these tracks only. A public bath is an attractive feature to the small boy. With him, however, cleanliness is not his primary object; it is perhaps more the sport of swimming in water, which is kept at a comfortable temperature. If the baths are free, their popularity is unquestioned, but stringent rules and first-class management are necessary; otherwise every privilege will be abused. Although something may be said in favor of public speeding tracks and public baths or natatoriums, yet, in general, if grounds can be secured adjacent to the main parks or boulevards for this purpose, they could be considered as an adjunct to the system, rather than a central feature of a park.

In every park of suitable size, it is desirable that some portion of it be so laid out as to accommodate the large numbers that usually attend the free concerts given during the summer months. The music grounds may or may not have a band stand, but the ground should easily accommodate a great number of vehicles, as well as pedestrians, and those who reach the parks on street cars. Temporary seating should be provided.

The flickering gas and gasoline lamps of a few years ago have largely been replaced by the more brilliant electric arc lights, to mark roadways and paths at night, and to brilliantly illuminate the boulevards. During the summer months, much of the driving, as well as the bicycle riding, is done in the early evening hours, and good illumination of all roadways is a much appreciated improvement. If the cost of operating 2,000 c. p. electric arc lights can be kept down to two cents per lamp per hour no serious complaint of the cost need be made, and if the number of lamps out does not exceed 2 per cent the maintenance is good. The electric light cables should be placed underground in permanent conduits, and suitable manholes should be provided for drawing in the cables. Socket sewer pipe is very often used for these conduits with success; they should be well reamed, however, so that there may not

be too severe abrasion of the lead sheath of the cables in drawing them in. The lamp should be of neat design, and none of the cables or wires should be exposed to view. The post should be of appropriate design, with a substantial base.

If the circuits will permit of it, a desirable plan is to have the lights on the boulevard on two circuits, thus enabling one-half of the lights to be shut down at midnight, and one-half to continue all night, if desired; also in case of accident to either circuit or dynamo, one-half of the lights can be kept in service.

Desirable as are the large outlying parks of a city, the smaller parks and squares are also of great importance. They should be distributed throughout the densely populated districts, wherever the local conditions will permit, or land can be secured, for they serve as breathing places and as playgrounds for children.

The boulevard system is no less important to the welfare of a city's growth than is its park system, and its construction and maintenance forms a considerable part of the park engineer's duties.

For a single drive boulevard, the width should not be less than 100 feet, to provide for a drive of proper width, as well as lawn spaces and sidewalks, although many city streets are reconstructed as boulevards whose width is only 66 to 80 feet. For a double drive boulevard, 200 to 250 feet in width allows an ample lawn space in the center for trees, shrubbery, or floral display if desired. A typical boulevard of this kind in Chicago is Drexel boulevard, extending from Fifty-first street to Oakwood boulevard. With a width of 200 to 250 feet, a three-drive boulevard may also be constructed by way of variation, but the lawn spaces must be considerably reduced, leaving them somewhat narrow for planting other than line shade trees. This style of boulevard is illustrated by Grand boulevard on the south side and Humboldt boulevard on the west side, both of Chicago.

All telegraph and telephone poles and wires should be strictly excluded from the boulevards, and even at the street crossings they should cross the boulevards in conduits in preference to the network of wires overhead.

It is impossible within the scope of this paper to enter into the subject of pavements, concretes and cements in detail. Volumes have been written on these subjects, and specifications clearly set forth what must be done and what must not be done, and a study of existing pavements shows the defects or limitations of each.

When heavy traffic wagons are not permitted on the boulevards the maintenance is rendered easier thereby, except at the intersecting cross streets.

The prime requisites of a boulevard drive are smoothness, cleanliness, noiselessness, safety, durability, moderate first cost, as well as low cost of maintenance, and ease of repair.

The writer is inclined to the opinion that but two classes of pavements for boulevards need consideration, and these are granite macadam and asphalt, although wooden blocks and limestone macadam are also used. The ordinary wooden blocks will show their weakness, whether they are used much or not at all, and their life is very limited, which is not true of a macadam drive, as this will last for years, especially with light travel, and repairs for it are easily made.

The use of thoroughly creosoted wood block pavement is not considered in the opinion above expressed. Here in Chicago the creosoted wood block has not yet been given a thorough trial, and the writer is of the opinion that this should be done in order to determine its usefulness as a boulevard pavement as well as a pavement for many city streets.

Some of the European cities, notably Paris, are using the creosoted blocks for pavements. The city of Indianapolis, Indiana, last year laid about 50,000 sq. yds. of creosoted pine block pavement, on concrete base, the cost of same being about $2.50 per square yard. Long leafed southern yellow pine was used for the blocks.

In order that this pavement may be compared with asphalt, since they are of nearly the same first cost, they should be laid on streets under similar traffic conditions and a record kept of maintenance cost and general serviceability, ease of repair, etc. In short, the creosoted block pavement should prove itself the equal or superior of asphalt pavement before extensive improvements will be undertaken with it; and much depends on the excellence of the wood used, aside from the special process of creosoting it undergoes.

In general, the process of creosoting indicated by the Indianapolis specifications is as follows: "After the blocks have been inspected and found satisfactory, they shall be placed in an air-tight chamber where, by means of superheated steam and the use of a vacuum pump, all sap in the blocks shall be vaporized and the moisture in them removed. When the blocks are thoroughly dry, and while the cylinder is under vacuum of fifteen to twenty inches of mercury, heavy creosote oil, of the grades known as Kreodone or Bee Hive creosote paving oil, especially prepared for paving purposes, shall be admitted into the cylinder and pressure added until the pressure in the cylinder shall be at least sixty pounds to the square inch. The blocks shall remain in the cylinder until they have absorbed twelve pounds of oil per cubic foot of timber, and until the creosote oil shall have impregnated the timber through the

entire thickness of the block and to the satisfaction of the Board of Public Works and City Engineer."

A good granite macadam roadway has the advantage of low first cost, noiselessness and ease of repair, and it does not deteriorate with time alone, as does asphalt or blocks; and it is not slippery. It, however, becomes muddy during an open winter and wet spring or fall months, and is dusty in summer unless kept well sprinkled, and its renewal is dependent largely on the amount of travel. It is not kept clean as easily as asphalt, nor will it stand heavy travel.

Asphalt pavements have the advantage in smoothness and cleanliness, as the street may be easily washed down with sprinkling carts; and it will fairly well resist heavy travel. It is more noisy, however, than macadam or wooden blocks. It is frequently very slippery and should not be laid on grades steeper than about 4 per cent; repairs must usually be made by an asphalt company. The deterioration of the pavement due to time alone, aside from the consideration of travel, is important, and the higher cost of replacing the top or wearing surface, as well as the higher first cost of the pavement, which is about two to two and one-half times the first cost of a granite macadam drive, must also be considered.

A granite macadam roadway may be constructed as follows: Upon a firm clay or sand soil, which has been properly shaped and rolled, from 10 to 12 inches of two-inch crushed limestone is compacted, and the upper surface is bonded with 1½ to 2 inches of bank gravel or limestone screenings. Upon this about 3 inches of 1-inch crushed granite is placed, and thoroughly bonded with the least amount of good bonding gravel that will secure the smooth, hard, resisting surface desired; usually 1½ inches in thickness is required. A thin coating of granite screenings is usually placed on top. Every layer of material should be well rolled with a heavy steam roller. One must look carefully to the quality of the bonding gravel; in order to secure good results it should not be too clayey, nor too sandy or stony, and when well wet it should form a hard surface after the steam roller has compacted it with the crushed granite. The frequent loosening of the crushed granite is a painful evidence of poor gravel, and spoils a roadway for bicyclists.

Asphalt pavements are usually laid on a concrete foundation, 4 to 8 inches thick; but where a good, firm macadam roadway has been in service, asphalt may be laid directly on such a base, and only as much concrete used as may be required for leveling up to secure good form. When a natural cement is used, specifications frequently require 8 inches of concrete and seldom less than 6

inches. When Portland cement is used, 6 inches are commonly specified, and seldom less than 4 inches in thickness is used, except as noted above. The mixture frequently used for natural cement is 1 part of cement, 2 parts of sand, 4 parts of crushed limestone; and for Portland cement, 1 part of cement, 3 parts of sand, 7 parts of crushed limestone; but these proportions are varied by different engineers and according to the particular material specified. After the concrete has set well, and when it will bear a heavy steam roller without breaking the bond, the binder course, 1½ inches in thickness, is usually laid, consisting of limestone coated with asphaltic cement, and upon this the wearing surface of asphalt, 2 inches in thickness, is laid. Extremely cold weather causes, perhaps, the most rapid deterioration of asphalt surface. Numerous fine cracks first appear during severely cold weather, and when dirt once finds its way into these the fracture does not cement itself again. Along the gutter lines the asphalt disintegrates more rapidly than elsewhere, unless they are kept very clean and are well drained. The causes for failure or deterioration in asphalt pavement are numerous, and no attempt will here be made to discuss them. A very comprehensive report on this subject may be found in the Annual Report of the Operations of the Engineer Department of the District of Columbia for the year ending June 30, 1899, under the direction of Capt. Lansing H. Beach, Corps of Engineers, U. S. A. The report is by Mr. A. W. Dow, Inspector of Asphalts and Cements.

In many places a combined curb and gutter of granite concrete is used in connection with the pavement, and in some cities stone or vitrified paving blocks are laid for a width of from 3 to 4 feet for a gutter. For the sake of appearance, it is preferable to have the asphalt pavement extend from curb line to curb line, and, if funds will permit, to have granite stone curbs for permanence. The laying of asphalt in the latitude of Chicago should be confined to the months included between May first and the following November first. Work is occasionally undertaken at other times, but the chances of obtaining a permanent pavement are decidedly reduced. Engineers are extending the period of guarantee on asphalt pavements to ten years.

For the construction of sidewalks and curbings on the boulevards, the granite concretes have come into general use. The cheapness and general adaptability of concrete for these purposes is undeniable, and with good material and workmanship the work is enduring. Much poor and defective work of this class is scattered about, no doubt due to indifferent inspection of material and workmanship, or to faulty foundation. The use of the combined curb and gutter is being largely replaced by the straight curb.

This is particularly desirable on macadam drives, as moderate wear of the macadam soon drops the surface below the outer edge of the concrete gutter, and perfect drainage is not secured.

The correct and economical maintenance of a park and boulevard system requires vigilance, and prompt and efficient service. It also means that for every dollar once expended in improvements, a certain percentage of that cost must each year be expended in care-taking. In a growing system this is a point occasionally overlooked, and with a fixed income new improvements may be hastened beyond the ability to properly maintain them.

DISCUSSION.

Mr. S. G. Artingstall—I think Mr. Schrader made the statement in his paper that the maintenance of macadam was very much less in cost than the maintenance of pretty nearly any other pavement. My impression is that on boulevards the maintenance of granite macadam pavement is very costly. While we admit the advantages, still the maintenance, if for a moderate traffic, should not be a very costly matter. It is probably the best pavement we can have for country roads, and for some of the roads in our park system, perhaps even for the boulevards; but if I am not mistaken the maintenance of a macadam pavement is very expensive, even under moderate traffic. Will Mr. Schrader inform me, if he finds it economical to maintain a macadam pavement on boulevards?

The Chair—In comparison with wooden or block pavements?

Mr. Artingstall—With wooden or block pavement or asphalt pavement, which are good in their proper places. Taking a moderate traffic, as much as we have on the park system, would it be economical or more expensive to maintain a macadam pavement against, I should say, wooden block pavement?

The Chair—Mr. Schrader, have you any data in relation to the maintenance—in relation to the wheel traffic on macadam roads? It is the general idea that a park road should conform to the ordinary dirt road as nearly as possible; that the pavement should not be distinctly a pavement, but simply a piece of improved earth road—that is the idea. Perhaps Mr. Schrader can give us the cost upon a certain amount of travel, the maintenance per yard, or unit of some kind.

Mr. Schrader—The question of comparative cost of maintaining the several classes of pavements is one which naturally first suggests itself to the engineer after the question of first cost has been considered. The first cost and the cost of maintaining a pavement should, of course, be considered together. It is not so difficult to find out the first cost of pavements, but the cost of maintenance,

in most of our cities, is not so easily arrived at. Aside from this, it must be borne in mind that many of our city pavements are not maintained in the full sense of the word; that is, but little effort is made to keep all streets up to a fair standard of excellence. On the boulevards this attempt is made, so that the entire system of drives may serve about equally well as pleasure drives.

To answer Mr. Artingstall's inquiry, I may say that the granite macadam has its field of usefulness and economy as a pavement on the outlying boulevards, but not on the heavy traffic inner boulevards. To illustrate this point locally, I would cite Humboldt boulevard, on the west side, as being particularly suitable for granite macadam. This pavement is eight years old, and no repairs have been made to it, and it is to-day in very fair condition. It is a light traffic boulevard.

The same character of pavement is used on Michigan avenue throughout its length, and is well maintained; but the cost of maintenance on the northern portion — say the portion north of 22d street — is undoubtedly quite high; probably 18 cents per square yard would be a fair estimate for cost per year. This is a very heavy traffic boulevard and requires re-surfacing about every two years. The two cases are cited to show the maintenance cost under the extreme conditions of boulevard travel — the one very light and the other very heavy — and they suggest the use of some other kind of pavement for the heavy travel boulevard. I presume Mr. Artingstall meant the ordinary round cedar block pavement, when he suggested the comparison of macadam and wooden block pavements.

The common round cedar block pavement, as laid in Chicago, is familiar to all. The life of this pavement is very short, whether it is used a great deal or not at all. Under heavy traffic the surface soon becomes uneven, full of ruts and holes, due no doubt to the lack of uniformity of the quality of the blocks. On light traffic streets they simply rot, and the life of such a pavement is probably not more than from eight to ten years at the most; and the last few years of such a pavement is not satisfactory, if we consider it as a drive for boulevard purposes, on account of unevenness, and it is, therefore, but little considered as a boulevard pavement.

It would indeed be very interesting if the Western Society of Engineers could secure a tabulation of the first cost, as well as cost of maintenance, of the various kinds of pavements used for city streets as well as the boulevards; but in so doing one must also know what sort of a standard of maintenance is accepted.

Humboldt boulevard, above cited, has two side drives paved with common cedar blocks, laid at the same time that the granite macadam center drive was laid, about eight years ago, and, as

before stated, the travel is very light. On these side drives the cedar blocks are rotting very rapidly, and probably two or three years additional service will complete the life of this pavement for boulevard purposes, and another pavement must be laid. As before stated, the granite macadam is still in excellent condition and has required no repairs.

Ashland avenue was paved with asphalt twelve years ago under a guarantee period of five years given by the contractors. During the last seven years the cost of maintaining said pavement amounts to about 2½ cents per square yard per year; but it must be borne in mind that the cost of maintaining hereafter, as the pavement ages, will undoubtedly be much higher, and that probably a considerable portion will require new asphalt top complete within two or three years, simply leaving concrete in place to build on.

Asphalt pavements, when well laid, should require but little or no attention for the first five years, except under very heavy traffic and at such points as street car crossings. With a good asphalt pavement a fairly heavy travel is preferable to light travel.

Mr. A. C. Warren—It is the custom in one or two foreign cities to specify crushed granite in concrete for sidewalks. What is the reason for using crushed granite rather than crushed limestone? I would like to have Mr. Schrader's opinion on this.

Mr. Schrader—Crushed granite is frequently specified for use in the concrete for sidewalks because it is thought to thus secure a concrete more durable and less affected by freezing and thawing than when crushed limestone is used. Limestone will absorb a much greater percentage of water than granite, and the repetition of freezing and thawing certainly doos not strengthen the concrete if limestone is used. Therefore, granite is specified for longer life.

Mr. Artingstall—I would ask Mr. Schrader whether limestone or cinder is used for bicycle paths, and whether or not cinders are suitable or even better than limestone or crushed granite?

Mr. Schrader—Well, for a sub-base, today we use cinders for a foundation everywhere and lay the concrete walk upon them. In fact, I do not know of any place where they use anything else, where they can get good cinders. Limestone is not used to any extent today. The concrete is laid directly on good cinders of about a foot in thickness; that is, referring to ground that has a heavy clay subsoil.

Mr. Artingstall—That is the question I wanted to bring out, because I know that cinders are generally used for a sub-base. I would like to ask whether cinders are not used principally on account of the drainage.

Mr. Schrader—Yes, it is the rule. It prevents the heaving of the sidewalk, especially on a clay subsoil.

The Chair—You use rolling mill cinders for a sub-base?

Mr. Schrader—Yes, sir.

The Chair—You have spoken of the maintenance of macadam roads. I know of one instance of a road built in 1888 and which has been maintained under a fairly heavy traffic without a dollar having been expended on it up to this time, and it is still a good roadway. Some of you may know the road; it is the drive from Fifty-first street to Jackson Park — East End avenue.

Mr. B. E. Grant—I would like to ask what the road cost per square yard — just to run it?

The Chair—I said without the expenditure of a dollar for repairs.

Mr. Artingstall—It is a pretty good street, to stand that for twelve years.

The Chair—It speaks for itself; you ride your wheel over it and you see how it is.

Mr. Geo. P. Nichols—I would like to know why it is that the gutter goes to pieces so much faster than the street. Is it not entirely due to poor drainage, especially as it is constantly besprinkled, or wet and dry, through the entire day? Is not the disintegration of the asphalt entirely due to evaporation? We have a beginning with cracks that are found in the asphalt; some are soft around the edges, and there are also hard cracks which radiate in all directions, and some of them are like creases. Now, are not these cracks due to evaporation?

Mr. Schrader—In reply to Mr. Nichols, I may say that, where the asphalt is carried to the curb — that is, where no concrete or block gutter is used — there is a strip varying from ten inches to about two feet that disintegrates, apparently by rotting, and loses its resistance so far that it may be dug out with the heel of your boot. It is due to poor drainage, or the wetting and drying process due to street sprinkling. A concrete gutter is desirable. On the central portion of the drive, disintegration usually begins by the formation of fine cracks during the very cold weather, and, once formed, these cracks rarely close again, on account of dirt filling the crack. Then it is only a question of time, and the cracks widen each year by abrasion and further disintegration. If cracks form within the first five years it would seem to indicate a lack of proper proportion of asphalt and sand. The sand should be properly graded, and should be of sharp and angular, rather than rounded, particles.

The Chair—Mr. Schrader, has the West Park system any specifications for street sprinkling?

Mr. Schrader—No, I think not. Mr. Chairman, there is one thing with reference to street pavements I would like to know about. Is there any one present who has had any experience with regard to the preservation of wooden blocks? A paper which I did not hear was read before the society recently, and I would like to inquire if the writer took up the matter of paving blocks, or did his paper have reference only to the preservation of wood?

The Chair—I will answer the question by saying that his paper simply had reference to the preservation of railway ties. The preservation of timber in general was taken up incidentally, but the discussion was on the preservation of ties.

WRITTEN DISCUSSION.

Mr. O. C. Simonds—There is little to criticise in Mr. Schrader's paper. Being written by a park engineer, it is natural that it should be largely devoted to the consideration of the engineering features of a park, but, while these are of the utmost importance for the comfort and convenience of visitors, they should really be subordinate to the scenery which is a matter of first importance. While a system of parks and boulevards may "serve as a fair index of the public spirit of its citizens," the true use of a park is in serving as a place of rest and recreation. By its quietness, its contrast to the busy streets and crowded buildings, by its broad, open spaces and great stretches of lawn and meadow below and sky above, it relieves the tension of tired nerves. The opportunity which a park gives for the residents of a city, who are constantly brought into too close contact with each other, to get away from their customary surroundings, and enjoy a certain measure of seclusion while breathing pure air, feasting one's eyes on the fresh green foliage, taking in the varied scenery, and perhaps listening to the songs of birds, is the real reason for its existence. It follows, therefore, that such buildings as are necessary should be unobtrusive and that roads and paths should be reduced to the smallest number that will accommodate those visiting the park. A paper on "Parks and Boulevards," to be complete, should discuss quite freely the principles of landscape designing, and the establishment and maintenance of plant growth as well as the establishment and maintenance of roads. I think that, usually, one does not stop to analyze that which gives him the most pleasure in park scenery, which is its general effect, any more than he reasons about the delight of breathing pure air. It all comes as a matter of course, but he carries away with him the image of a tree to which his attention has perhaps been called by its profusion of blossoms, or its great size, or he remembers a particular shrub or flower, but these

are mere incidents; and incidentally, too, a park furnishes a place for children to play, and a place for picnics and for exercise.

More might have been added in regard to the selection of sites on account of their adaptability. Those who know the cost of planting trees or moving earth will appreciate the importance of securing the most attractive woods there may be about the city, or the most pleasing slopes or hills or valleys; and, of course, the margin of lakes and rivers should be secured where possible.

Mr. Schrader says "the placing of monuments commemorative of historical persons or events in parks is evidently considered desirable by many park boards. The total absence of such monuments in some of our principal park systems may evidence a contrary opinion." The fact that there are two opinions so opposed to each other should lead to the greatest caution in regard to the introduction of monuments. Too often the effect upon the scenery of the park is not considered when the admission of a statue is proposed.

The suggestions made in regard to drinking fountains, water systems and drainage are excellent. Where the grades are steep, catch basins should often be placed less than two hundred and fifty feet apart, and the distance of two hundred and seventy-five feet may sometimes be increased with very flat grades. In the parks of small towns, a roadway much less than thirty-five feet in width is often ample to accommodate the public.

The remarks in regard to the accommodation of people attending the concerts, the lighting of parks, the location of smaller parks and squares, the exclusion of telegraph and telephone wires, are all instructive and I think will meet with general approval. It is evident that we have not yet devised a perfect park driveway, but the paper fairly states the advantages and disadvantages of each kind of pavement. It seems to me that there are many places where a curb is not needed; and where it is necessary it should on all accounts be kept quite low.

The remarks in the fore part of the paper in regard to continuity of management are timely and wise. If a scheme could be devised by which the appointment of park commissioners could be entirely divorced of politics, and selections made solely from a consideration of ability and fitness, a long step in advance would have been taken. It is gratifying to come upon men in control of parks who occupy their positions on account of their knowledge and experience and of the love they have for their work. It is also gratifying to have the Western Society of Engineers take up the question of parks and boulevards, and I hope much good will result from the discussion of this subject by its members.

Mr. H. C. Alexander—It has been said that every man has his hobby which he parades in public more or less frequently. The

paper is disappointing to one searching for Mr. Schrader's pet, as he has carefully avoided bringing any one feature of park building and maintenance into such prominence as to overshadow other important subjects, and has also covered the ground so thoroughly as to leave little to be added except in the way of elaboration. The public does not go to the parks to admire the walks or drives, yet these two features are apt to be forced upon their attention, and an opinion of the park in general is often based on their recollection of the condition of these two improvements. The designers of parks often lose sight of the practical part of park construction, and will expend thousands upon thousands of dollars in beautifying the grounds, and successive boards of commissioners will add beautiful and expensive attractions in different portions of the grounds, and yet remain content to use materials in the construction of the principal walks that are, at best, only makeshifts. If limestone, gravel and the abominable cinder are good enough for park purposes why use the tidy and evenly laid cement and asphalt walks on our residence streets and along the boulevards? A macadam walk is far from being an ideal one at any time of the year and is, according to the season, liable to be either muddy or dusty. Good walks are as necessary in a park as elsewhere, and in the older cities of this country the park authorities have acknowledged the truth of this, by building cement and asphalt walks. Good walks add both to the comfort of the visitor and to the appearance of the park, for in no other way can the disfiguring foot paths worn in the turf parallel to the walks be prevented and the use of the unsightly wire or chain fence be obviated.

If Mr. Schrader's advice as to working from carefully prepared plans were followed, the walks could be placed at the beginning of the building of the park where they were to remain and, with permanent walks, the amateur landscape gardener would be checked in his pursuit of annually trying this or that alteration in walks or planting.

It should be possible to go from any entrance to the principal points of interest in the park on a walk that is clean, dry, smooth and not too serpentine. Especially should this question of direct paths be taken into consideration in the laying out of small parks with any amusement features and likely to be frequented by large crowds of people. It is obvious that in large parks greater leeway as to landscape effect of curved walks can be permitted.

Engineers are generally agreed as to what goes to make a proper concrete or asphalt walk, so that little need be said on the question of construction. These walks should be laid on a bed of at least six inches of sand or cinder which has been thoroughly compacted. There is no occasion to use granite in what is called the concrete,

as limestone is suitable for this purpose; and a walk laid with four inches of concrete composed of one part of Portland cement to three parts of limestone screenings and five parts of crushed limestone (sidewalk concrete size) and covered with a granite top dressing of ¾ inch in depth, made in the proportion of two parts cement to three of fine granite screenings, will, if proper attention has been given to quality of cement and manner of using materials, last indefinitely. Care should be taken to give an opportunity for expansion.

The foregoing remarks are also applicable to the construction of the combined curb and gutter.

Mr. Wm. A. Peterson—The inherent beauty of every landscape is largely derived from the trees which enter into its make up. Trees are also very important factors in softening or accentuating the handiwork of the architect. Nothing is so restful to the eye or such a balm to the tired nerves as nature's own mantle of green. These gigantic air filters make the climate healthier, equalize the temperature, and by their beneficent effect bring heaven and earth into more perfect harmony.

Formerly, the tree planter went out to some neighboring forest and selected a sapling of the desired variety and of a size he could handle. After digging, it was found to have only three or four main roots and devoid of fibres. The reduction of the base of supplies to nearly a stump necessitated an equally heroic treatment of the trunk and branches. Should the tree survive this trying ordeal, it is hardly to be expected that such material would ever produce a symmetrical effect. The training of a boulevard tree must begin in its infancy.

One should collect seed from a good thrifty specimen of the particular variety and habit desired, then sow in rich soil and transplant every third or fourth year, giving, each time, just enough space to form a straight trunk and a well shaped crown.

This frequent transplanting forms a great mass of fibrous roots, which are the mainstay of all trees destined to be moved later on in life. The annual trimming is done with reference to obtaining a stocky trunk and a well developed crown, sufficiently high to not interfere with carriages or street lighting. The young tree, now some three or four inches in diameter, can be graduated from the "Baumschule," as the Germans call it. When extra heavy large sized trees are required they may take a post graduate course into heavy soil, in order to obtain a transportable ball of earth and roots, even if not frozen.

Upon entering business life in a city the young tree is confronted by many trials and adverse surroundings. The soot and smoke stop up its lungs; tall buildings shut out the air and sunlight;

ashes and other refuse are expected to nourish the roots, and the much needed rain speedily finds its way into the sewers. Is it a wonder that city trees do not always prove a permanent success? Nevertheless, the nursery grown tree is better equipped for these difficulties than his brother from the forest. Fall and winter are the seasons when the trees are most dormant and can best be moved.

A modern fad is to make an irregular treatment in the tree planting, setting some trees against the curb and others as close as possible to the sidewalk, and at various intervals omitting them altogether. Plant one variety only, in a line, and at least thirty-five feet apart. A straight avenue is plainly the work of man, so why not have the trees conform to it? What can be grander than a vista through an overarching boulevard of stately trees? I use the term boulevard as the French do, and not for a narrow street regularly swept and sprinkled by a park board.

It is not safe for us in the west to blindly follow all the recommendations of the eastern specialists. The Brooklyn Tree Planting Society gives first choice to the pistillate form of the Ailantus for an avenue tree, and in Paris the same preference is shown. With us it has not proved a success, as it winter kills badly. The severe winter of a year ago wiped out 95 per cent of all the tulip trees also.

Oaks grow slowly and are so riddled by borers that they must be discarded. The various members of the Birch family are all very beautiful, but after removing the lower branches, as is necessary on a driveway, their narrow pointed tops have an unnatural appearance. The American Sycamore thrives better here than its more aristocratic relative from Asia, but both are erratic and unreliable. The Horse Chestnut does not take kindly to our climate, as all old trees will be found to be rotten at the core. For a flowering street tree the western Catalpa is an excellent substitute and quite tropical in its suggestion, and is a vigorous grower. The so-called Caroline Poplar is a seedless form of this numerous family, closely resembling the common cottonwood, and it is the popular tree of the day. With an erect habit and rapid growth it combines a dignified disregard for soot and smoke and, like the Catalpa, thrives in clay or sand. The thornless Honey Locust has a light feathery foliage and is esteemed by many. Our Teutonic friends favor it, for its resemblance to their beloved Acacia. The irregular and low branching habit of the Box Elder makes it more suitable for screen work. The Silver Maple is of quick growth and, if the top is properly trained, is more shapely than the slow growing and more rigid Sugar Maple, but both have a host of admirers. If the Elm is "king of the forest," then the Norway Maple is its "queen."

It is free from all attacks of insects, leaves out early, gives a grateful shade, and is the last to drop its autumnal tinted foliage of rich gold color.

The experimental stations have found the Hackberry, in appearance much resembling the Elm, to best withstand dry parching winds, and long seasons of drought. For formal planting the Linden and Rock or Cork-barked Elm are very much in vogue.

In selecting an ironclad variety to withstand all adverse circumstances the White Ash easily takes the lead. The soil may be light or heavy, be flooded in the spring or badly cracked in summer, yet with no attention whatever the Ash will grow right on. The Bronze Ash, botanically known as Fraxinus Americana Petersonii, is a local form embodying the good points of the Ash just mentioned, with a dark green foliage, holding late, and with fine autumnal colors. The English Field Elm is of much slower growth than the American and has a smoother bark. It does not transplant as readily and, owing to a tendency to become sour-hearted, is not used in the west except as a lawn tree. Several varieties of the Scotch Elm are beginning to find favor as street trees. But the noblest and grandest of them all is the American Elm, the ideal boulevard tree.

Some people imagine that a goodly sized Elm cannot be transplanted with any degree of success. In substantiating the claims which I have made, I can cite the result of 540 Elm trees, five to six inches in diameter, planted on Ridge avenue in Rogers Park three years ago, of which not a single tree died.

Mr. C. D. Hill—The particular portion of Mr. Schrader's paper that is of most interest to me is the portion that treats of boulevard pavements. The conclusions that he draws are justified by experience in Chicago. It is quite true that the most satisfactory pavements for boulevards in this locality have been found to be asphalt and macadam. One of the reasons for this is that these pavements compare most favorably with other pavements when they are maintained in perfect condition, as they are in a well policed boulevard. On the other hand, they do not always compare favorably with other pavements when they are allowed to become filthy and are not promptly repaired when occasion requires it. It is because of this fact that many people have become prejudiced against one or both of these pavements. Macadam is so generally regarded as a cheap and dirty pavement that it is almost hopeless to say anything in its favor, except to point out the many miles of excellently maintained macadamized pleasure drives in and about Chicago. Asphalt pavements are generally regarded by the public who only travel over them as exceptionally clean, and if by chance some street paved with asphalt is allowed to become filthy and in

bad condition the fault is not laid to the pavement but to the neglect of public officials who are unable to give it proper attention. On the other hand, people who are obliged to live on a street (not a boulevard) that is paved with asphalt are outspoken in their denunciation of it as being not only noisy but filthy. Because of the smoothness and extreme dryness of its surface the small amount of filth on it becomes pulverized into a fine dust that is constantly being blown about and penetrates into adjacent houses in spite of closed doors and windows. Because of the immediate evaporation of water, sprinkling does little or no good, and it is for this reason that the best maintained boulevards paved with this material are swept dry by the patrol system, with an occasional flooding with water at night.

The cost of maintenance in the case of each of these pavements is very great. When there is a great deal of traffic the whole surface of a macadam pavement wears down quite rapidly, and necessitates a renewal of the surface every few years, besides the constant expense of patching. In the case of asphalt the cost of maintenance is very uncertain. The durability of the pavement seems to have little relation to the amount of traffic, but in some manner to be dependent on the proportions of the mixture and the manner of doing the work. The source of the supply of the asphaltum is of less importance than the manner of treating it, the amount of flux used, the quality and quantity of the sand used and, especially, the skill that is used in the whole process of mixing and laying the pavement. In order to insure the durability of this pavement it is necessary to take into account all of the local conditions, not only of soil and traffic but of the amount of sunlight and moisture, and to regulate the proportions of the mixture accordingly. Judging from the results obtained in Chicago, none of the companies laying this pavement here seem to be able to solve this problem successfully. If one reads the occasional articles written for the technical journals by the scientific experts employed by the various asphalt companies, one is impressed with the unanimity with which they disagree with each other. It is, therefore, difficult to form very definite opinions either from theoretical considerations or from practical experience.

It is to be regretted that one of the park boards of commissioners has not paved a portion of one of the boulevards with creosoted wooden blocks. This pavement is more expensive than asphalt, but it is claimed to be superior in every other respect. If it has all the virtues that are claimed, it would make an ideal pavement for a boulevard. It has been used somewhat in this country, and is quite popular in Europe, especially in Paris. Last fall the road-

way of Rush street bridge was paved with this material and I believe that is the only sample of the pavement in this city.

In this connection, attention might be called to the pavement laid five years ago in Michigan boulevard from Van Buren street to Congress street. This pavement consisted of rectangular pine blocks, in their natural condition, laid on a concrete foundation. The pavement was covered with a heavy coat of paving tar or asphalt that apparently protected the blocks from decay during the first year; but, at the end of two years, it was necessary to replace some of the blocks and now, after five years, the pavement is in wretched condition and is beyond repair. The adjoining portions of the boulevard, paved at the same time with brick and macadam, have given much better service.

The conditions under which a boulevard pavement exists differ so widely from those to be found in ordinary streets that it is unsafe to apply the conclusions drawn by Mr. Schrader to pavements that are not perfectly maintained and that are subject to heavier traffic. Under such conditions it may be advisable to pave the gutters with a different material than is used on the rest of the roadway, especially in the case of asphalt or macadam pavements; and there are many streets where vitrified brick will give better service than either of the two pavements that have been found to be most satisfactory for boulevards. The mistake has sometimes been made, by inexperienced engineers and officials, to consult park engineers on this subject, and, by misapplying the information in the attempt to improve country roads and village streets, get very poor results.

SECOND ORAL DISCUSSION.

The Chair—To open the discussion, I would like to ask Mr. Hill if creosoted block has established its worth as a pavement? Last year I happened to be in Indianapolis, where they have a number of streets paved with creosoted block, and, upon inquiry, one of the citizens informed me that in his opinion, while it might answer for the residence district, it did not give satisfaction on heavy traffic streets.

Mr. C. D. Hill—I have no personal knowledge on the subject; but it has a good reputation among the promoters. [Laughter.] And, aside from that, I also heard a gentleman connected with the Ogden-Sheldon Company, who had been abroad, speak of it, and he was very enthusiastic on the subject. I don't think he is promoting the material either. He said he had been taken all over the streets of Paris with the officials there, and they always apologized when they took him on one of the asphalt streets, saying that was one which they had not replaced yet. I don't know that they use

pine blocks so much in Paris. In London they started in, using blocks from Australia. The promoters in this country talk as if nothing but Georgia pine was used anywhere.

The Chair—I know the promoters state that Indianapolis is one of the places where creosote block has given so much satisfaction.

Mr. C. D. Hill—That is the home of the promoters, I understand.

Mr. John H. Warder—One of our visitors here tonight asks if any of us know anything about eucalyptus blocks for street paving. They have been used in the continental cities.

The Chair—Mr. Schrader, do you know anything about that block for street pavement?

Mr. Schrader—We have had no experience whatever with creosote block pavement in Chicago.

The Chair—Is Rush street bridge the only place where it has been placed in Chicago?

Mr. Schrader—Yes. I am not informed as to the exact process or treatment these blocks were subjected to. I understand that the South Park commissioners will make a trial of creosote block pavement in Chicago on, perhaps, half a block on Michigan avenue, within a very short time, so that we shall have an opportunity of seeing what it can do on such a boulevard. That will hardly, however, give us any clue as to what it will do on a heavy traffic street.

Mr. H. W. Parkhurst—Will some one say what they are putting in now in the block on Michigan avenue where the wood paving was, which has been referred to this evening; that is, between Van Buren and Congress, I think?

Mr. William Black—It is a pressed asphalt block. It is compressed with asphalt, instead of putting asphalt on, as is usually done.

The Chair—Is it just asphalt, or what do they use as a binder, if anything?

Mr. William Black—The asphalt is the binder.

Mr. John H. Warder—Then it is virtually a brick pavement?

Mr. C. D. Hill—In that particular block they use crushed granite. It is a very large, heavy block, smooth, and with square corners. It does not seem to be much harder, if any, than vitrified brick.

The Chair—Does any one know what sort of stone they are using on Madison street where they are repairing the car tracks?

Mr. C. D. Hill—Those particular blocks are granite, from Berlin, Wis. The same kind of blocks has been laid down for many miles in the city, with the exception that these blocks are dressed very true, and the tops are smooth and the sides smooth, so that they make very true joints. The result is, you get a pave-

ment that is practically as smooth as a brick pavement and more durable. At the same time, it will probably be more slippery than the ordinary granite pavement. On the other hand, the joints being small and the tops flat, the blocks are not apt to wear round, as is the case with most of the old-fashioned granite block, and that will prevent, to a certain extent, slipping, at least the disagreeable effect of the horses' feet slipping and catching at the joints. Of course it will make a much smoother pavement and one less noisy. The block is laid on concrete and a sand cushion. The depth of sand under each block is the same as that under the adjoining blocks, and thus one block will not settle more than another.

The Chair—I notice the old blocks that came out of the street there were worn quite round on the edge.

Mr. C. D. Hill—Nearly all of the old granite blocks wear that way, and that is the cause of the great noise in travel over the streets—the joints are so broad and deep.

Mr. H. P. Boardman—Is not that Belgian block pavement?

Mr. C. D. Hill—That is the general term used years ago for a dressed stone block.

Mr. W. A. Peterson—Another point in Mr. Schrader's paper which can profitably be enlarged upon is that referring to the common custom of introducing into large park areas inharmonious objects, such as statuary, bicycle race tracks, museums, etc., thereby obstructing any lengthened vistas, as well as detracting from the natural beauty of the scene.

The Chair—I think, myself, it is a question well worthy of discussion. Mr. Schrader ought to be able to give us a little more extended information on that subject.

Mr. A. C. Schrader—I cannot add much to what I said in my paper. Such an improvement, for instance, as an extensive bicycle track, as we have in Garfield Park, takes up so large a proportion of the park that it is made a central feature, especially if the park is not of any greater extent than are ours on the West Side, and it leaves only a very narrow margin in which to get any real park effects. Such improvements as that, I think, can well be relegated to grounds adjacent to the parks and boulevard systems. The object at the time this track was built was to lessen the racing on the boulevards. It grew to be quite an annoyance—granting permits to the bicycle fraternity to run their races two or three times a week on the main boulevards—and, in fact, it shut out much of the pleasure driving on the boulevards during those hours, so that this was one of the reasons why the track was placed in Garfield Park. It was thought also it would meet with the approval of a very large number of people who enjoy that sort of thing. Bicycle racing, pure and simple, is indulged in by a very small percentage of those

who ride a wheel. In regard to the placing of monuments, I do not know that I made myself clear in the paper read. I think that all monuments which are placed in parks should be very carefully selected, or, at least, approved, by some special art committee. We ought not to have any monuments in our parks and boulevards which have not been passed on by artists and sculptors before being accepted. A suitable place for such monuments, as I think I indicated in my paper, is in the small parks and squares. We have not very many of these here in Chicago, especially in the business portion of the city, but we hope to make up for it by some day having a grand lake front park. At the intersections of the boulevards, where they are somewhat wider than the average width of the drives, there are very good places for monuments. I don't think it quite appropriate to dot them around a large park, especially where there is a natural plantation. It should be done, if at all, where there is a formal laying out of the grounds, to be consistent.

Mr. John H. Warder—I would like to say something on tree planting, and the distinction between boulevard tree planting and park tree planting. As has been mentioned in this discussion, it is necessary to have some so trimmed up that the branches will not interfere with the driving of carriages and the lighting of the street on the boulevards. In the parks it is entirely different; that is the natural habitat of the tree; there we can have the beautiful conical form of the Norway spruce and other trees of that character where the branches come down to the ground. That is proper in parks, but utterly out of place in boulevards. So with the birch. If that is properly trimmed up to allow passage on the boulevards it is out of form. One needs to study these points a little, and observe these trees, to see how beautiful many of them are in the parks and how out of place they are in the boulevards.

XCIII.

THE NEW ENGINEERING BUILDING OF THE UNIVERSITY OF WISCONSIN.

By J. B. Johnson, M. W. S. E.

Read May 11, 1900.

In reviewing the design of this Engineering Building, the factors to be taken into consideration were:

First. The room available on the campus.

Second. The slope and character of the ground.

Third. Conformity, as far as possible, with some predominant style as shown by the surrounding buildings.

Fourth. The necessity to complete the structure in all its details, inside the appropriation of $100,000. This, too, after the cost of labor and materials had risen some 25 per cent over what they were when the appropriation was made.

In the matter of the location, the site most available was a contracted one between a large red brick building, Science Hall, on the east, and a rectangular stone building, North Hall, on the west.

In the matter of the ground, this available space was rendered difficult of treatment by reason of a steep grade, falling from west to east at least twelve feet in one hundred. In this connection it is well, perhaps, to refer to the first arrangement contemplated in connection with the location and construction of this building. In May, 1899, a call was issued for competitive plans, the call dictating the building of a half of a proposed scheme, the half to be built with a narrow face on the main campus, and a long facade on the east or down hill side, facing the present boiler house and chimneys, which, it should have been said before, are between Science Hall and this site.

The two competitions, lasting from May until September, produced no satisfactory scheme. Not only did all plans presented far exceed in cost the amount of money available, but all failed to produce a satisfactory elevation of the building with its future extension on the west added. In all cases this requirement was either ignored or an elevation was presented which gave the appearance of two adjoining buildings on a hillside, the basement of one on a level with the second story of the other.

Finally, the Regents of the University determined to place the whole matter in the hands of the Dean of the College of Engineer-

ing and the Superintending Architect, Mr. J. T. W. Jennings. Mr. Jennings put in sketches the ideas, always held in common by both of them, that the front, presenting the artistic difficulties, should be at first completely worked out in detail, and the space on the central campus on which all the buildings face, or border, should be filled in with a structure presenting three perfect facades as seen from each accessible point of view.

No well defined style had been used for the buildings as a whole. The two oldest, North and South Halls, are perfectly plain rectangular stone buildings, with square-head doors and windows. At the head of the campus University Hall had recently been added to, and its style brought into a semi-renaissance, or, as is commonly called in this country, a colonial style. Opposite the Engineering Building stands the Law Building, of Lake Superior brown sandstone, in the modification of the Romanesque, fathered and elaborated by the late H. H. Richardson. To the east of this stands old Library Hall, a feeble Gothic. On the east of the Engineering Building site is the boiler house, low in the ground with no style, and having two plain, inharmonious chimneys* ; and towering above this again to the east is Science Hall, of no particular style, built of red brick and all out of harmony with its surroundings. Across the lower campus, recently constructed, stands the beautiful Historical Library Building, of white stone, elegantly designed in the renaissance style, so called, and to the south, a block away, Ladies' Hall, recently altered to a style conforming somewhat to University Hall and the Historical Library. These three buildings taken together, and with the fact that the North and South Halls can only be made presentable by a similar addition of classical ornament, pointed plainly to the choice of renaissance, modified to suit the adaptations to the uses of the proposed building, as the style to be employed in the Engineering Building.

For color, it was at once decided to adopt a gray. For material, brick, terra cotta, and blue "Bedford" oölitic limestone were selected. The brick is hydraulic-press brick, No. 503, set in a pink mortar. This mortar is composed of lime, Milwaukee cement, and sand, and is colored by an oxide of iron. We found from an extended examination of gray brick buildings that a white mortar looked ghastly, a black mortar looked funereal, and a gray mortar gave a dead and uninteresting facade to which no one would give a second glance. We found one building in Milwaukee with the pink mortar, and this at once decided us. This mortar mingles with the gray of the brick at a short distance, giving the impression of a gray granite.

* It is now expected that the boiler house will soon be removed and placed under the bluff on the lake shore.

The portion of the building under erection at this time is less than half of the contemplated and complete design. The completed building shows a rectangle, with projecting corner bays and a central court. This court will be wholly occupied by the steam and mechanical testing laboratory, the portion now building being only one-half of the final court area.

In the matter of cost, an unusual provision was incorporated in the bill to the effect that the contract could not be let for anything less than a completed building, nor for a sum exceeding $100,000, and it required the Governor's endorsement that these conditions had been complied with.

Description of the Exterior.

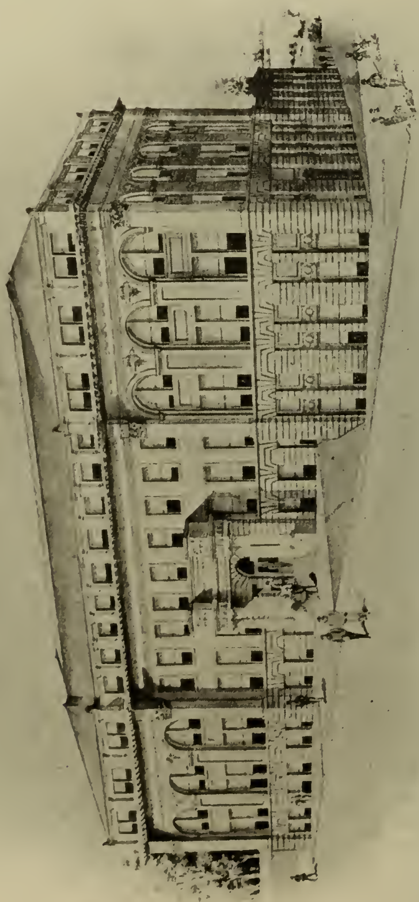
At the height of the first story windows a base line of a heavy stone sill-course is carried horizontally around the entire structure; this, for artistic reasons, is the tie-line or starting plane on which the design is developed.

Below this the basement story, stepping down the steep grade of the hill and accomplishing practical functions as hereafter explained, is an entity. Where the height is so great as it is on the east, and where the basement story proper has been omitted for reasons to be given later, the omitted story has been taken advantage of to place terra cotta panels, bearing the motto and seal of the state, surrounded with the laurel wreath and palms, over the windows. The design is symbolical of the awarding of honor to the memories of persons to be commemorated by the inscription of their names and some symbol of their accomplishments on stone tablets set over the panels described. These panels and tablets serve also to lighten up the heaviness of appearance given by the excessive height of basement wall on these faces. They are also dignified and pleasing in appearance.

The basement is "rusticated," or every sixth course of brick sets back one inch to show a line and shadow, after the classical detail of the order of the Doric, as used by the Romans in the lower and heavier stories. The central entrance on the south front rises from this basement midway between the basement and first stories, and presents a handsome portico of Bedford stone. The flanking columns on the sides of the entrance carry above their Doric entablature two pedestals bearing the names of Stephenson and Watt, and which it is intended to utilize some time for bronze statues of those great engineers. The aim of the architect has been to concentrate the mass of the ornamentation on the facades of the bays, leaving dignified and restful spaces with simple fenestration or window arrangement between for the eye to rest on, and accenting, without crowding, the entrances in the centers of these facades.

Above the sill-course, capping the basement story, the style is the Roman Corinthian, its proportions, except for necessary modifications, being carefully preserved.

Each bay is flanked at the returning corners with a pilaster with terra cotta base and Corinthian capital, on which is imposed the main cornice of terra cotta, all carried out in the richest detail of the Roman Corinthian. Between the corner pilasters of the bays occur the arcades, the impost course and archivolts of the arches being in strict classical design and proportion.



Engineering Building, University of Wisconsin.

In the spaces or spandrels between the arches are placed ornamental cartouches of terra cotta, with shield and foliation in classical design, whereon are imposed floating ribbons bearing the names of great engineers to be honored. The following names have been selected for this purpose: On the east the names of Bessemer, Reynolds and Gramme; on the south (the front) the names of Ericsson, Kelvin, Rankine and Siemens, and on the west the names of Henry, Corliss and Telford. The only name of a living American engineer is that of Edwin Reynolds, of the E. P. Allis Works, Milwaukee. As a great engineer and a Wisconsin man we thought he merited this honor.

Above the cornice occurs the clear story, and above this the roof, purposely kept as plain as possible to set off the simplicity and dignity that has been aimed at in the general design.

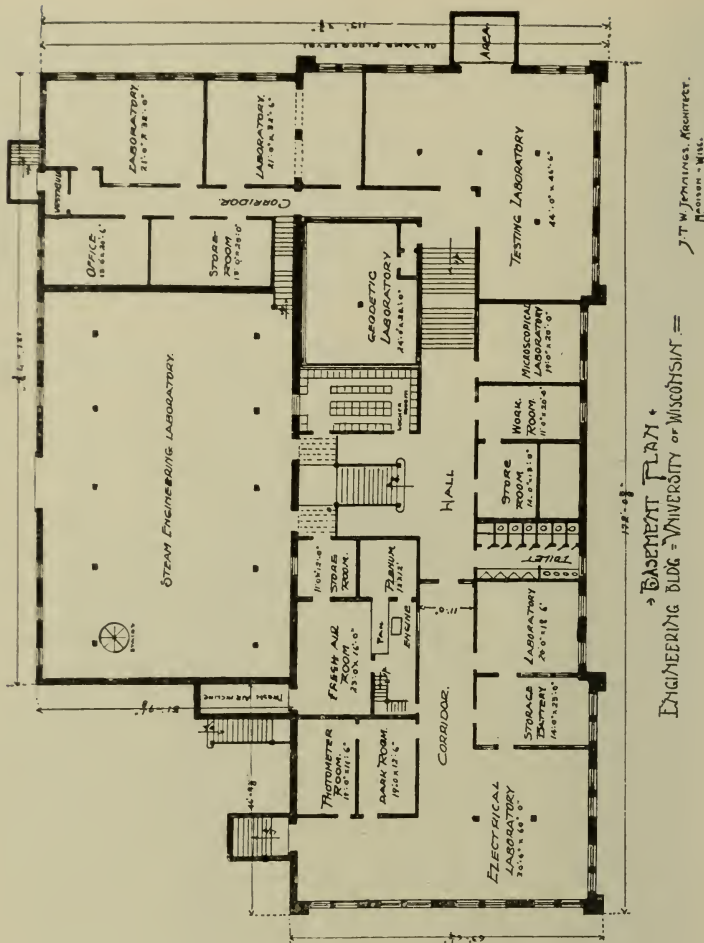
The slopes and terraces are to have their stiff lines and angles softened, and the building given a proper setting by judicious planting and parking in its immediate vicinity.

Before describing the interior arrangement of the building it is well to call attention to the omission of the windows of the basement story proper, at the southeast corner. Here three stories in height are made into two stories in order to add to the height of an assembly hall on the first floor. This floor is here depressed some eight feet, and the sub-basement story is made high enough to absorb the remaining portion of the basement story proper. This explains the ornamental panels and the stone tablets which surmount them in this story at this part of the building. There being twelve of these, it remains for us to select twelve engineers to be honored by their names and by appropriate designs symbolizing their contributions to engineering science. The use of these ornamental panels and stone tablets was suggested by President Adams.

Attention may be called also to the unobtrusive skylights in the roof which light the drawing rooms in the attic story. One should note also the absence of any chimney or ventilating shaft or other excrescent attachment at the top of the building to mar the majestic repose of this part of the structure. There is, at the back, a large ventilating shaft, and also a blue-printing room, raised above the lower edge of the roof, but these will be invisible from every point when the building is continued around the court in which has been placed the steam engineering laboratory.

The Basement Story.

This story is on two levels, the east portion, or sub-basement, being depressed one story below the central and western portion. In the higher, or basement story proper, are located some electrical experimental laboratories, photometer rooms, microscopical labora-



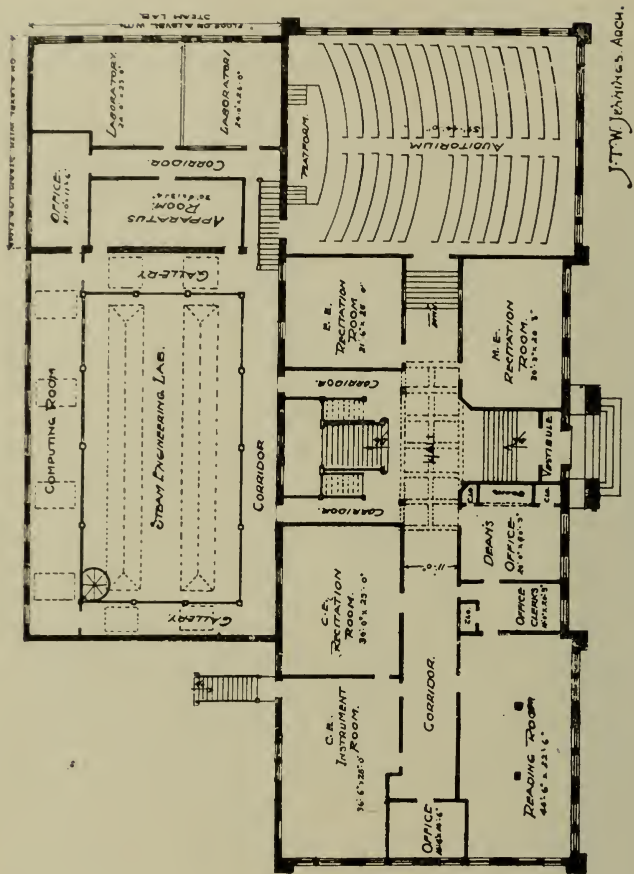
tory, and the fan rooms of the ventilating system, besides store-rooms, toilet rooms, and a large locker room. The building is heated wholly by direct steam radiation, but all recitation and drawing rooms, and the assembly hall, are thoroughly well ventilated by the plenum fan system. Both the direct and the indirect heating systems are controlled by the Johnson automatic regulator service. The air distribution ducts in the basement are all below the level of the floor line, the fan room being depressed six feet below the level of the basement floor. It must be understood that the regular electrical dynamo and motor or power laboratory is located in a building adjoining the work shops.

The sub-basement, under the east end of the building, is occupied by the testing laboratories for testing the strength of materials, a cement laboratory, and the temporary hydraulic laboratory. A large hydraulic laboratory building will probably be erected within a few years upon the lake shore. There is also in this portion of the building a geodetic laboratory, or comparing room, built with double walls, ceilings and doors, with no windows, and mostly underground. This is for the purpose of maintaining here a temperature quite unaffected by the diurnal changes of the outer air, and subject only to a very gradual season change.

On a level with the basement story proper is the Steam Engineering Laboratory, which occupies what will ultimately be a part of the court when the building is entirely completed. It is lighted from the roof and also now from the open north side. The east and west walls will ultimately become the outer walls, on the side of the court, of the side extensions. When the building is extended this court area will be enlarged and the Steam Laboratory extended to twice its present size. The tunnel, carrying all the steam pipes from the boiler house, comes to the rear (north) door of this laboratory and all the steam distribution pipes in the laboratory will be below the floor. This laboratory will be surrounded by a gallery on a level with the first floor, which will serve a double purpose of a computing room for the experimenters and an observation platform for visitors. The entire State Legislature visit us occasionally, and here they could come all at once and see the students at work below. The north side of this gallery is shut off from the laboratory space by a glass partition, and this is well lighted by windows on the north. This is the computing room proper. The laboratory is well provided with ventilating shafts, and some of the skylights also will be hinged. Off from this laboratory on the east, on the same level with it (shown on the plan of the first floor) is an office room, an apparatus room, and two laboratory rooms for coal and gas analyses. These appear on the first floor plan as though they were on a level with the gallery, but this resulted from there being an extra story in this part of the building, a basement proper and a sub-basement.

The First Story.

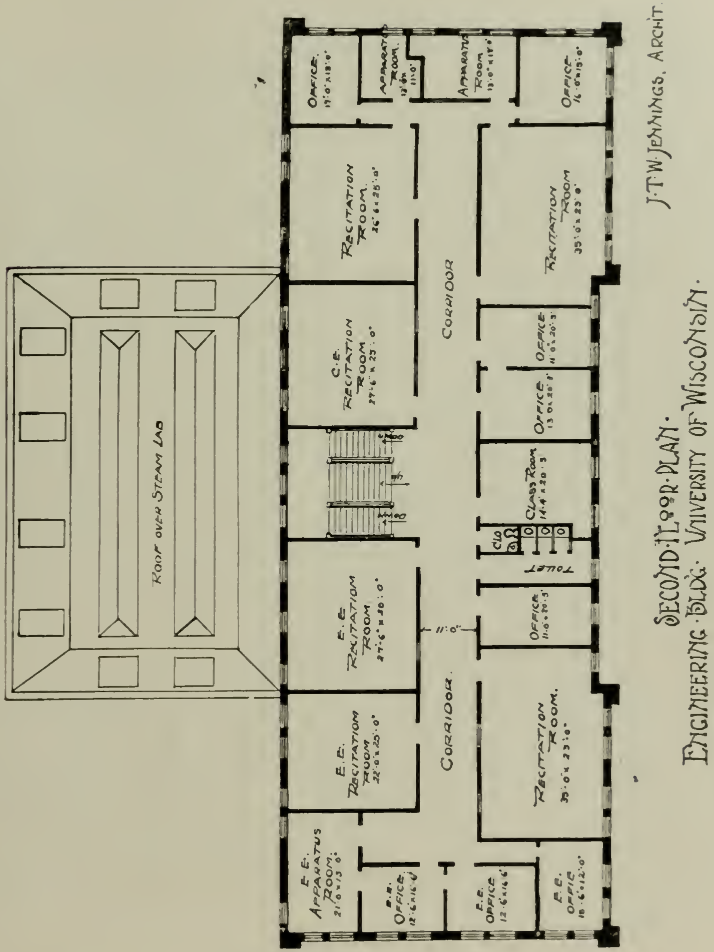
The entrance hall will be as much a feature of the interior as the entrance itself is of the exterior. . It is roomy, and will be finished in marble and quartered oak. The stairway is immediately in front, with side corridors leading to the gallery around the Steam Laboratory. Turning to the right, in the main hall, we pass down a flight of steps some six feet to the raised and sloping floor of the auditorium. This contains a raised platform, and has seats for



— FIRST·FLOOR PLAN —
ENGINEERING BLDG. = UNIVERSITY of WISCONSIN.

three hundred and fifty persons. It will be used by professional non-resident lecturers. Entrance to the platform is effected through the gallery of the Steam Laboratory and a flight of steps. It is expected that shallow museum cases will be placed about the walls of this room for specimens of interest to the public.

I may here state that the interior of the building is mill construction, with a metal lath and a hard and practically fire-proof plaster. The plaster will be left with a gray coat and all the walls will then be water-colored in various tints, with a modest amount of color decoration. The partitions will all be hung from the ceilings with slip joints at the base-boards to allow for the shrinkage of the floor timbers without cracking the walls. The columns will be plastered in, but with circulating holes in the top caps and in the wooden bases to allow of an air circulation for seasoning, and to prevent



dry-rot. The timbers are all genuine long-leaf southern pine from lower Mississippi. Turning to the left on entering, one passes the private door to the dean's office and enters the outer office, where there will always be a clerk. Just beyond this is the reading room and duplicate technical library. The dean's clerk will have immediate charge of this room, a door opening directly into it from the clerk's office. Across the hall from here is the surveying instrument room and the surveying lecture room. Direct entrance to the instrument room from outside is effected from the rear of the building, this door being nearly on a level with the ground at this point. The instructors in surveying have their offices at the end of the hall adjoining the instrument room. There are two other lecture rooms on this floor.

The Second Floor.

This is the main office and lecture room floor. There are here eight offices, six lecture rooms, one seminary room, three apparatus rooms, and the professors' toilet room. The ends of the halls throughout the building are all utilized and the halls are lighted through the stairway opening on the north and through glass doors and numerous glass spaces in the hall partitions. The blackboards are all to be of slate.

The Third and Attic Floors.

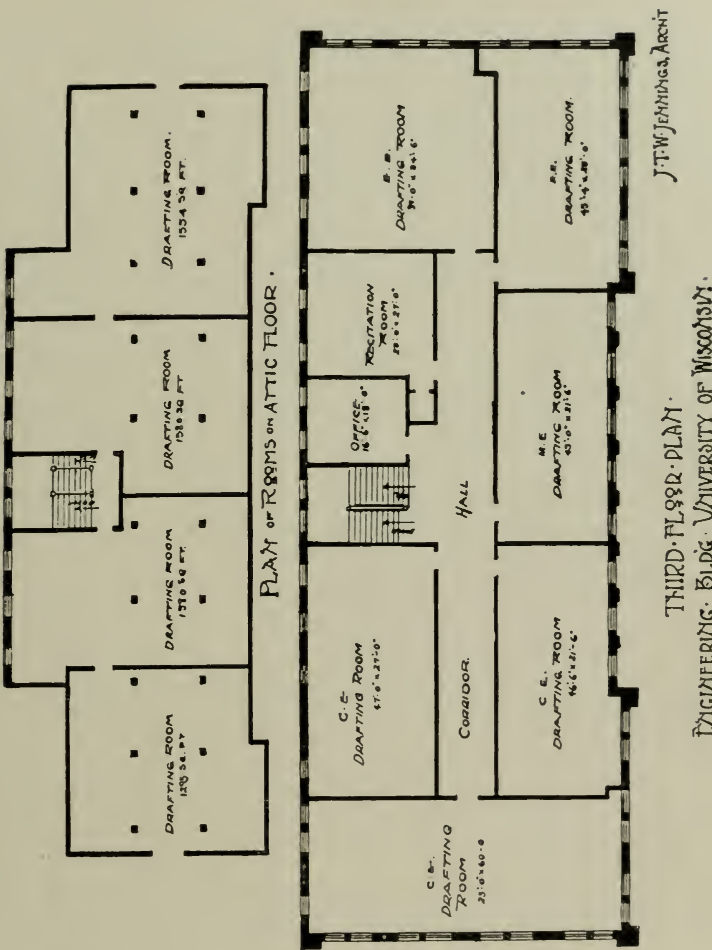
These are given over wholly to drawing rooms except that one office and one class room are provided for on the third floor. The attic floor is without hallways, and is lighted wholly by skylights running the whole length of the roof on both sides of the ridge. A blue-printing room and tracks are provided just over the stairway area on the north side of the roof, as a fifth story room, the tracks extending out along the roof, east and west. Counting this and the sub-basement, the building occupies six levels. These two upper floors provide ten large drawing rooms, but these may soon be overflowing.

Artificial Lighting.

It is proposed to light the drawing rooms and the auditorium, when artificial light is required, by means of arc or powerful incandescent lamps so arranged as to be entirely hid from sight by opaque reflectors, which will disperse the light as uniformly as possible over dead white ceilings, and the reflection from these will light the rooms. How well we will succeed in this remains to be seen. At any rate no strong glaring lights will be visible in any of these rooms.

Time of Completion.

The duty of preparing plans was turned over to Mr. Jennings and the writer early in November, 1899. The plans and specifications were completed early in January. The contract was let February 1 to Frederickson & Sons, Madison. The excavation was all completed in March, the frozen ground having to be blasted out. At this writing, May 16, the walls are completed to the level of the main floor, the material is all on the grounds, and there seems to be no doubt that the building will be completed ready for occupancy when college opens the last week in September next. If we succeed in this we will have set a new pattern in Madison for speed of construction. It is safe to predict, also, that for beauty, both of outside and inside, for adaptation to its uses, and for economy, this



building will be quite as marked as for the dispatch with which it has been constructed. The building will be fully completed, including all the excavation, steam heating and tunnel for steam pipes to boiler house, electric wiring, lighting fixtures, and engine and machinery foundations in the laboratories, for the sum appropriated, $100,000. This is far beyond the expectations of the Board of Regents when the plans were first presented to them.

The heating plans and specifications were prepared by Prof. Storm Bull, and the electric wiring plans by Prof. D. C. Jackson. Prof. Turneaure served as chairman of a committee of the engineering faculty on the arrangement of the floor spaces. In other respects the building has been planned by Mr. J. T. W. Jennings, the Super-

intending Architect of the University, with more or less advisory assistance from the writer. The exterior, however, is wholly the work of Mr. Jennings.

The front of the building is one hundred and seventy-two feet long, from which the other dimensions may be estimated. The best of materials have been employed throughout. The roof is of slate, and all the windows in the south and east exposures are of the best plate glass. The terra cotta work, including the very wide cornice course, is a splendid product, and was made by the American Terra Cotta & Ceramic Co. The fact that the third floor was to be used wholly for drawing room purposes allowed the use of high windows, or rather the omission of the lower portions of the windows on this floor, thus making room for the wide cornice course which adds so greatly to the appearance of the building. The building will be a thing of beauty as long as it stands and will, I trust, long continue to serve not only its practical uses, but also to stand for many generations as a silent influence to shape the æsthetic tastes of the thousands of students who constantly haunt these grounds.

DISCUSSION.

Mr. F. L. Hill—I would like to ask Professor Johnson how he accomplishes the hanging or the suspension of the partitions to the upper floors?

Prof. Johnson—The partitions are composed of studding, with wire lath and a hard plaster. The studding will be attached to the bottoms of the floor timbers above, either the floor joists or the floor girders as the case may be. The columns, we will suppose, do not settle, and the walls do not settle, and therefore the bottoms of the floor timbers do not settle; it is the tops of the floor timbers that are lowered by the shrinkage of the floor joists and girders laterally. All southern pine timbers are cut to order and are always green when put in the building, so a 12-inch plank will shrink from a half inch to three-quarters in width in drying, and every floor has to come down by that amount. The top of the floor comes down but the bottom of the floor or ceiling does not. Now, if partitions are made to rest on the floor they will come down, but if they are hung from the ceiling above they will not come down.

Mr. J. H. Warder—Are the supporting columns for the floor above carried in the line of the partitions?

Prof. Johnson—Some partitions are in line with the columns, but not all. They can be set directly under the joists. The joists are 16-inch centers, and the studding of the partitions will be hung

either directly under the joists or directly across the joists. In either case the studding can be attached to the joists.

Mr. J. H. Warder—Are the columns placed without regard to partitions? In ordinary floors we use the partitions as supports.

Prof. Johnson—The partitions in this building do not support anything. The partitions are entirely free from the floor systems. All the partitions in the building can be moved at any time at pleasure.

Mr. B. B. Carter—How is the joint made at the floor?

Prof. Johnson—It is a slip joint. The base board is nailed to the studding and is varnished to the floor line. The base moulding is two inches high and is attached to the floor. This is put on after the base board is varnished and is left free from it. This makes a slip joint between the base board and the floor moulding. This method of hanging the partitions, and the slip joint, are Mr. Jennings' invention, I believe, and it is a good thing. In this way we hope to prevent all cracking due to settling. All the walls are to be water-colored and more or less decorated.

Mr. T. L. Condron—I would like to ask what the approximate saving in the entire cost of the building has been through using mill construction, over steel fire proofing?

Prof. Johnson—We did not carefully figure on a steel interior. We knew we could not use it, and get a building as large as we required for the sum appropriated. There was not much time to figure anyway. Besides, the mills were all reported six months behind on orders and we feared to delay the building.

Mr. J. H. Warder—Are the columns cast iron?

Prof. Johnson—No; they are long leaf pine columns. It is not a fire proof building exactly, but we use a wire lath with acme plaster, which is the nearest fire proof of any hard plaster, and it is near enough fire proof; that is, if it is heated red hot and water is thrown on it, or if it is thrown into the water, it will crack some, but it will not come off the lath.

Mr. J. H. Warder—I would like to ask in regard to the artificial lighting; have you heard of its having been done in the way you describe?

Prof. Johnson—I was told that there was an assembly room in the Art Institute in this city which is lighted in this way, but I have never seen such a room.

A Member—Fullerton Lecture Hall in the Art Institute is lighted in that way.

Prof. Johnson—Our idea would be this: to have either very strong incandescent lights, or arc lights with a horizontal feed. Then with opaque reflectors, properly shaped, the light might be

distributed uniformly over the ceiling. We could have these shaped to special designs for this purpose.

A Member—Where are these lights to be placed?

Prof. Johnson—We want them placed on the sides. If they are placed in the ceiling they would cast shadows from their own attachments.

Mr. F. L. Hill—I understand there is a room in Chicago, in the Jewish synagogue on Indiana avenue, where the light is placed up near the ceiling, on top of a projecting ledge, and not visible. There the auditorium room is quite high, so that the projecting ledge is permissible and not out of place. In a low ceiled room that would not be practicable. The effect is very satisfactory.

Prof. Johnson—I notice this, that where the light comes down from the top, through skylights or from windows, it is deceptively strong on a book or drawing board placed horizontally. If you look around in the room you see dark corners and shadows, and it seems rather dark; but if you are working on a drawing board, the light comes straight down on that, and it is surprisingly well illumined.

Mr. Byron B. Carter—I heard of a drafting room in Cincinnati, Ohio, in which that same scheme was employed. They had arranged the drafting room with the lights over the boards, in the ordinary way, with the bracket fixtures, and they used half-cup reflectors to throw the light down; but in order to make the room lighter during the day, when the work was generally done, the ceilings were painted a pure white and the lowest portions of the windows were screened off with white muslin curtains, so that the direct light would come through the windows, the effect being in the daytime for the light to be reflected from the ceiling; and I understand that by turning the cup reflectors upside down and throwing their artificial light upon the ceiling they got the light distributed over the room better, and there were no shadows formed upon either triangles or T squares. After experimenting with it some time, they made the fixtures shorter and put the lights up within about three or four feet of the ceilings. I understand that this was very successful, and I think, from that, that your scheme will work, and I should think that there is this advantage, that it would not be necessary to distribute the lights all around the sides; these reflectors will not cut off enough light to produce shadows.

Prof. Johnson—I think engineers should take a little responsibility upon themselves in this matter of lighting. I believe, as I said in the paper, that such lighting as you have in your room here now is barbarous. I do not see any reason in it; we all know better, every one of us. We know we do not have to do it, and yet

we allow the lighting men to come in here and do for us the things we know far better how to do ourselves. Now, why should we submit to this? We not only should not submit to it for ourselves, but we should tell other people what should be done, and make other people's business our business a little more, and go out of our way to advise people how to illuminate rooms. I believe we are all going blind from these strong artificial lights.

Mr. B. B. Carter—I take the same stand that you do. I believe that in lighting a house, instead of making drop fixtures as they used to do for gas, and getting them down where you can handle them, it is a great deal better to put the lights as far as you can upward, and then screen them from below by reflectors which throw all the light to the ceiling, and distribute it over the room. You would then see no bright light except the reflected light from the ceiling. In the place where I live, we lighted a church on a similar scheme. We put the lights with transparent shades right up against the trussed beams, and it is a most satisfactory arrangement. There are only eighteen 16-candle power lights in the room, the room being about 28 x 44 feet, and there is a perfect light. You can read a paper anywhere.

Prof. Johnson—Are the lights up so high that they are out of sight?

Mr. B. B. Carter—They are so high that they do not bother. They are not as high as we would like to have them, but they are as high as we can get them.

Mr. Warder—I understand your idea is to have your heat and your power, your electric generation, and all that, put in your new power house, but in your steam engineering laboratory you carry a certain amount of steam simply to operate your machinery and to run the different types of engines; is that a part of your plan?

Prof. Johnson—Yes.

Mr. Warder—Will you also have electric generators in your laboratory simply to illustrate the types?

Prof. Johnson—There may be a few small electric motors and generators in that basement, but nearly all that work is in another place; all our electric power machinery is in another building.

Mr. Warder—Will that new electric power station be completed by fall?

Prof. Johnson—No; we will have to go to the Legislature for that. We want to make so good a record on this building that they will give us anything we ask.

Mr. Carter—Are your engines and boilers in that plant now?

Prof. Johnson—We have a boiler station, or boiler house, where these chimneys are, that has to be removed; but then we have large shop buildings and electric laboratories in another building—

that is, the machinery and shop building. The electric power will remain in this shop building and the extensions of it.

Prof. Kerr—I would like to ask Prof. Johnson if he has as good a scheme for heating and ventilating as he has for lighting?

Prof. Johnson—Well, I think so. We have a perfect system—a system of forcing the air for ventilating purposes in large quantities into the rooms. The openings, where the air comes into the rooms, are very large, so that in the coming in of these great masses of air into the room, the speed is so low as not to create a perceptible draft or breeze. That is something that is usually neglected. It is common to have a fan of sufficient capacity and to have a heating capacity sufficient in the fan room, but the ducts and the gratings or areas for admission into the rooms are usually so small that in the first place one does not get anything like the quantity he ought to have, because the ducts are too small, and then when it does come in it comes in with a rush, and creates a draft and a disagreeable effect in the room. The secret lies in having large ducts, and openings into the rooms very much larger than the ducts, so that while the air passes at the rate of ten or twenty feet per second in the duct, it comes out into the room at a speed not exceeding six feet per second.

Prof. Kerr—Do you either heat or moisten the air for ventilation? I judge you do not rely on that for heating?

Prof. Johnson—No; we expect to have the ventilation air either seventy or below, whatever seems to be necessary. The building is to be heated wholly by direct radiation, under automatic control, so as to hold the temperature of the room at seventy degrees, and thus the fresh air will be any temperature we please. That will also be controlled by the Johnson system of automatic regulation.

Mr. Warder—Are you going to heat with the ugly radiators that are in the market now, or can you devise something more æsthetic?

Prof. Johnson—We are not proposing to invent new radiators: we will have to take what we find.

Mr. Carter—Is anything done about keeping out the smoke and dust?

Prof. Johnson—All the air in Wisconsin is clean and remains clean! We do not expect to take any Illinois or Chicago air into the building.

Mr. Warder—But you have got dust there; I know from experience.

Prof. Johnson—There will be little or no dust on the bank of the lake where this building stands.

Prof. Kerr—Do you think it unwise to rely on fans for getting heat as well as ventilation?

Prof. Johnson—Yes; it is a mistake, I think, to rely on indirect

or ventilating air for purposes of heating. For instance, take our assembly room; there will be no air forced into that room until it is occupied. We can hold the heat there constantly, but we do not want to change the air in that room except when the people are there making it foul, so we do not want to rely on the indirect or hot air system for heating the room; accordingly, when the rooms are not in use the fans stop, but the temperature is held up.

Prof. Kerr—In other words, it is a scheme for saving coal.

Prof. Johnson—Yes; the indirect system is a very expensive system of heating, because as much hot air goes out of the building as cold air comes in, and all the hot air that goes out contains wasted heat unless it goes out foul; all pure hot air that goes out carries so much waste heat.

Prof. Kerr—Have you these air ducts leading into your store-rooms?

Prof. Johnson—No; there is no ventilation to any of the rooms except the drawing rooms, recitation rooms and assembly rooms. Our offices, even, have no fresh air supply. There are never more than two men in these offices, and seldom more than one, and the door is usually open when the office is being used. There is no fresh air coming into the hallways, because there is plenty of ventilation of the hallways through the open doors, so we save a great deal there, too, in the heating system. We not only save the ducts and the registers and the extra quantity of air that would be brought in by taking air into all the rooms, all the offices, apparatus rooms and hallways—we not only save all that, but we save the automatic regulation in those rooms. Each automatic regulator costs a great deal of money.

PRESERVATION OF TIMBER.

WRITTEN DISCUSSION ON PAPER XC.

Presented May 16.

Mr. S. M. Rowe—Mr. Chanute has added much of value to the too limited knowledge in regard to the subject under discussion, by his extended researches, and it is only with the desire to contribute my mite that I take part in the discussion.

To avoid prolixity, I shall confine my remarks to a few points taken up in the order of his article.

The Visible Timber Supply.

Comparing the present condition of the forest, in the scope of our knowledge, with that of 30 years ago, the improvident destruction of our trees forcibly brings to mind another wanton and complete destruction, all within about the same time, a destruction on much the same line, but very much less important from a humanitarian point of view—that of the American bison. In this latter, we have the compensation that the same range now supports great herds of domestic cattle.

From the present and increasing rate of the destruction of our forests, unless something is done, the result will be no less complete and the condition will have no mitigation.

It is not this consideration, however, that would influence the railroad manager to go to the expense of treating the ties and timber for his railroad. He will view the matter from an entirely different standpoint, particularly when good white oak ties are out of reach by reason of distance, and resort has to be had to the softer and less lasting timbers that are within reach. He knows, when he has constructed his line, and by the time his roadbed and track have been brought to a fair degree of stability, that he will be obliged to turn loose upon it an expensive force of tie renewers to destroy much of what has been done to get a good track. Could he have laid his track with ties that could be depended on for twelve years instead of four, the story would read much better, especially in a financial sense. He would have two renewals of ties, with their constant disturbance of roadbed and track, saved. I have not as yet seen the difference between the two cases figured out, where the estimated savings anywhere near approached the actual savings, especially where the constant disturbance of the roadbed and track was properly or sufficiently considered.

The Application of the Glue Separately from the Chloride Solution in the Zinc-Tannin Process.

While in cases like that of the Atchison, Topeka & Santa Fe, at Las Vegas, in 1885, where large quantities of well dried ties were available, there was no difficulty in getting sufficient absorption, yet when we consider conditions where this is not the case, where measurably green-cut ties must be put through, anything that will facilitate absorption is very desirable. Another consideration comes in here. It is supposed that the glue is strained out of the solution when it enters the timber, and that its absorption is largely superficial; yet, should it go beyond the reach of the tannin penetration, it would be of itself detrimental to the timber, it being likely to decompose and facilitate decay.

Impairment of Strength of Timber, by Treating by Zinc-Tannin Process.

A careful examination of the mountain pine at Las Vegas, in 1887, where a plank was ripped lengthwise and one-half treated and both halves thoroughly dried and worked into test pieces, the result of tests for transverse strength was decisively in favor of the treated timber, the strength of solution being from 1½ to 1¾ per cent and the steam carried being 20 pounds.*

From close observation of the manner in which the spike penetrates the treated tie, my impression is that the timber is very much less crushed or shattered in driving than in the untreated tie. The section men will all agree that in treated ties the spikes drive easier and are much less likely to turn or go wrong.

It is inconceivable that even a 4 per cent chloride solution should render the timber brittle, and the probability of such resulting from excessive steam pressure with its attending heat is great.

Manner in which the Solution Penetrates the Timber.

While it is true, as Mr. Chanute says, that the penetration is largely by means of the sap ducts, yet much of it must come transversely to these ducts, and, by thorough steaming, a very large proportion reaches the heart timber in this way. Mr. Powers, chemist of the Atchison, Topeka & Santa Fe R. R., has made some careful tests in regard to this, finding a surplus near the ends of the tie and in the outer ¾-inch of the side surface, and finding the body of the tie almost uniformly permeated with a less quantity.

*Corroborative of this, see table 13 by Mr. Noyes, in Mr. Curtis' valuable paper on "Artificial Preservation of Railroad Ties by the Use of Zinc Chloride," read before the Am. Soc. C. E., where tests of spike hold and transverse strength are given both for untreated and treated timber.

This test was made on a sawed heart tie from the mountain pine of New Mexico. This case seemed to lend strength to the idea that the solution did distribute itself throughout the tie, the test having been made some considerable time subsequent to being treated.

The writer treated a loblolly pile, 38 feet long and of standard size, with creosote, where the penetration at the middle of the stick was almost complete. In this case nearly 30 pounds per cubic foot was absorbed and was a very good illustration of the effectiveness of the work, but somewhat appalling to the parties paying for the oil. This timber is very open and somewhat spongy in its texture; and sawed heart Texas pine, close grained and somewhat heavily charged with resins, could scarcely be forced to take 12 pounds per cubic foot. This difference in absorptive power is found everywhere, and even in different parts of the same tree; hence, it is very difficult to judge just how best to handle the timber and to judge just what results are really attained.

It is in no wise clear that all timbers are not capable of benefit from treatment. The softer are benefited in a greater degree, undoubtedly. But because an oak, or a close grained heart pine, absorbs less by half than the softer wood, it does not follow that it is not the better tie, in consequence of its stronger and more compact fiber.

Green and freshly cut timber can be treated by prolongation of the process, but there is a risk of disappointment in results that will more than counterbalance the expense and care of allowing nature to dry it to such an extent as to secure proper absorption. No better drying kiln can be devised than this, and, if a little care and forethought are exercised, the danger of failure from this cause will be eliminated.

Live and growing timber, with its natural saps and its sap cells in their normal condition, resists the introduction of any fluid when freshly cut, much on the same principle that two bodies cannot occupy the same identical space. To introduce the fluid, the natural saps must either be evaporated or they must go through a process of fermentation which is the initial step toward decay. If the timber, on being cut, is immediately exposed to high temperature and conditions favorable to free evaporation, the tendency to fermentation is lessened, and rapid drying will prevent decay—as in air seasoning in a dry place or in a drying kiln. In such case there is little alteration in the sap cell organism; but if, on the other hand, the timber remains in a damp condition, especially in a damp, warm climate, fermentation of the saps will commence almost immediately, with resulting fungi of decay, and the delicate organism of the cells will be first attacked. The more delicate and

less compact portion of the timber is first destroyed, and next the firmer portions are attacked until, in a few months, the timber becomes spongy throughout. Timber in this condition will give off its saps freely under steaming and will readily absorb the treating solutions. Microscopic examination of the timber in each case will show this disarrangement of the sap cells, and treated timber will show the effect of the steaming in much the same way.

Taking a sample of timber that has been treated, and a similar sample of untreated timber, both cut to length of four inches (a condition the most favorable to natural absorption of water when immersed in it), we find that the treated sample absorbs the water more slowly at first, but that the rate of absorption keeps up until at length, after 90 days, the two reach about the same degree or per cent of absorption.

We deduce from this that, by the breaking up of the delicate organism of the cells, the timber is rendered less capable of immediate absorption, the broken down cells obstructing the passage of the water by their spongy condition, retarding but not preventing the final filling of all the cells. In the case given by Mr. Curtis,* the gelatine and the tannin might cut some figure, but in the case before mentioned it could only affect the outer superfices, the end wood being far from that portion of the stick exposed, the block being over two feet from the end of the stick when treated.

Hence, we should conclude from this that, in the case of softer timbers, the process of decay should be allowed to progress to a point where this breaking down of the cells takes place, to get the most favorable conditions for absorption.

During this period, considerable sap would be thrown off in evaporation ; and, if this point could be fixed with any degree of certainty —a point at which decay has not in any measure reached the true woody fiber of the timber, but at which a sufficient amount of the sap has been evaporated to render the timber fairly dry for handling—then we will have settled the question of how long timber should be allowed to dry before treating.

Marking Ties for Identification.

We have found the hammer stamp sufficient, so far, to make a lasting mark on the end wood or on the beveled kerf of the tie. It is much cheaper and easier to apply, the only requisite being that the hammer be heavy enough (say four pounds), with the die cut perpendicularly, furnishing a thin, square face of sufficient

*See "Artificial Preservation of Railroad Ties," p. 371.

depth so that the stroke will carry the wood fiber to a sufficient depth to prevent it swelling out to its former position.

ORAL DISCUSSION.

Mr. Onward Bates—I have not read Mr. Chanute's paper, but I know its value and intend to read it. I have given the subject consideration, as a user of timber, and, for at least a dozen years, I have been upon every occasion an advocate for the preservative treatment of timber. I know something of the econ nical value of a treatment which would extend the life of timber u. ed in railway structures. I am at this time doing some work at a site adjacent to a saw mill in Northern Michigan, and am using fir timber from Puget Sound, and long leaf pine timber from the Gulf of Mexico. Some of this fir timber is cut from trees probably a thousand years old, and in our service it will not last more than ten years. Our timber supply is nearly exhausted, and in addition to the domestic consumption we are shipping timber in great quantities from our eastern and our western seaports to all parts of the world. Our country is being robbed of its wealth of timber and we are consuming it at such a reckless rate that most of us who are here will live to see a day of repentance. Any man who gives the preservative treatment of timber fair consideration must be an advocate of it on the score of patriotism. I know of no one who has given more attention to the subject of preservative processes for treating timber than Mr. Chanute, and I have such great respect for his opinions that I am prepared to indorse his paper, even if I have not read it.

A Member—This discussion mentions the fact that the driving of spikes is .easier in the treated timber than the ordinary tie. I would like to ask Mr. Chanute what he finds to be true, and if the treated tie holds the spike better than the tie which has not been treated?

Mr. Chanute—The ease in driving depends very much on the time in which the spike is driven. If it be driven immediately after the treatment, and while the timber is yet full of the solution injected into it, the spike doubtless goes in more easily, but all our experience is that after the tie has dried out, the treated tie resists driving and holds the spike very much better than the untreated tie, so that the hemlock ties, which we have been treating here about fourteen years, are found to hold the spike as well after the second year as the oak tie does the first year or two. The oak tie is probably superior in holding powers at first, but after four or five years the hemlock, which if untreated would not hold the spike

well, is found nearly equal to oak in its holding power. While I am up, I may add I am very much gratified at the confidence that Mr. Bates has expressed in the general subject of treatment, and I want to say that success is not only a matter of process but also a matter of the care with which the process is carried out, which is just as important. We erected, some years ago, an experimental plant and we have been extending our experimenting as to the results of various modifications of the process, and we find it is in the manipulation, in the thorough permeating of the whole of the wood with the solution, that success lies. With regard to the points made by Mr. Rowe, I may say that I do not quite agree with him as to the time at which it is best to treat the timber. Much depends upon the condition in which it has come to the works. We find in the spring of the year, for instance, that some ties reach us freshly cut and so full of the watery substance of the sap that they are unfit for treatment. We find later in the season that those same ties, which should come to us dry and in proper condition, have been rafted out to the vessels, thus saturating them, and we now make it a practice, whenever a cargo comes in, to inspect it and to weigh a number of the ties, and we then make up our minds whether they are in fit condition or not. The year before last there were some seventy thousand ties which the railroad people were very anxious to have treated, as they were in need, but we persuaded them to let us put the ties on the ground at our own expense in order to get them in proper condition; last year we did the same thing with a hundred thousand ties, at considerable cost to ourselves, until we had satisfied ourselves the ties were dry enough. In the first years we had not done as good work as we desired—and that brings me to another point—as to the marking of the ties. It is not sufficient to do this with the stamping hammer. That is what we are doing at the works here, but at our new works at Mount Vernon we are not only stamping the tie with a hammer, but we are furnishing at our own expense a galvanized nail for the purpose of dating the tie, in order to be dead sure to be able to identify it ten or fifteen years hence. We do that because we found that upon one of the railroads here the records as to where the ties had been laid had gotten into such condition that there was no telling what was the age of those in the track, and the report went out among the men that our ties were giving out in three or four years, and, at the maximum, in seven years. The question was only settled by the heroic measure of having the ties counted in the track, twelve millions of them, whereupon it appeared that the statements that had become prevalent upon the road were not correct, and that, knowing the number that had been furnished and the number that was still in the track, it was proved that they were

lasting, instead of five or six or seven years, an average of nine or ten years—although that, I think, is not enough; we wanted to do better. So in order to preclude the possibility of any such question coming up hereafter, we have undertaken, in new contracts, to furnish the nails at our own expense, so that there shall be no question as to the age of the ties.

Mr. J. H. Warder—In putting in the dating nails, are they driven by the men after the ties are put in the track?

Mr. Chanute—They are driven on the top face, about ten inches outside of the rail, where they can be seen in walking along the track.

The Chair—I would like to ask Mr. Bates if he would advocate the treatment of the Oregon fir timber that he has used in his railroad construction? I have an idea that that is the best quality of timber that is being used in railroad construction for stringer bridges and wooden truss bridges, and it is a question with me whether it would be advisable to treat such timber as that?

Mr. Bates—I am not prepared to answer that question—as to the Oregon fir—because the layers of hard wood in it are so very dense; and I have heard it said that the preservative solution will not penetrate through these dense layers. If the preservative solution can be forced into the timber I am in favor of treating it, because there is no question that the timber, if left to itself, will decay within a short time. When we first commenced using fir timber (and I think our road was the first one of the roads east of the mountains that used it to any extent) they told us in Washington that the timber would not last in bridges more than about six years. I took it anyhow, assuming that the decay was due more to the rainy days they have in Washington (about 120 a year, I believe), and I have found since then that this timber after ten years' use is still in good condition, and have concluded that in this climate it will last longer than pine. Even if it lasts twelve years without treatment, I think its life will be increased to fifteen or twenty years by treatment, as shown by Mr. Rowe in his notes, and if this is the case it will be economical to treat it. We have to consider the labor as well as the cost of the timber itself in counting the cost of renewing structures. I wish to be considered an advocate of the treatment of timber, but do not claim to be an expert as to the best method of treatment.

Mr. B. E. Grant—I want to endorse one of the things Mr. Bates has said and to take exception to another. He says that the country is being robbed of its wealth in the way of timber, which is undoubtedly so. In the State of Washington, for instance, I saw a strip cut across the country there for a pole line; the trees there grow to an immense height—two hundred feet or more—and men

cut a strip through a large part of the country, anywhere from fifty feet to five hundred feet wide. All that timber was just burned up to get rid of it. The statement that I want to take exception to is that referring to the 120 rainy days; I would like to amend that and make it 320. Out in that same country the Seattle & International Railroad built toward the Cascade mountains into Snoqualmie a line of railroad, twelve years ago, and it has only just begun to renew its ties and there, in some twenty miles, I think it is, it has some sixty trestle bridges anywhere from twenty to one hundred feet high, and up to seven or eight hundred feet long, and in all that time it has never had one of them burned up, which I think is due to the rainy days they have there.

The Chair—Taking up the question of treating the timber in truss bridges, I think the Howe truss bridge costs about half as much as a steel span of the same length. Now, if the treatment of that timber would add very much to the cost of it, it is a question whether a railroad would go to the expense of getting the timbers treated, rather than go to the expense of getting the permanent bridge. I do not know how much it would cost to treat the timbers of a Howe truss bridge, but as to the lasting quality, I know of an instance where a Howe truss bridge had been up for thirty-one years and the timber was all in a good state of preservation when it was taken down; it was taken down because it was too light for the present traffic. The year after, they took down a bridge that was up for twenty-seven years. Both were covered Howe truss bridges.

Mr. S. G. Artingstall—At our last meeting I asked Mr. Chanute a question as to what effect the treatment would have upon the strength of the bridge. I think his answer was to the effect that in compression members it did not affect the strength and possibly gave an increase of strength, but as regards the tension members his views were that there would be a decrease in strength.

Mr. H. P. Boardman—How would this treatment affect the transverse strength of the stringers?

Mr. Chanute—The treatments with the mineral salts are somewhat injurious, as I understand it, to the tensile strength of the timbers, and I have invariably discouraged railroads and other consumers from having any timber intended for lower chords or stringers treated by any of the mineral salts methods. I believe that the injection of creosote does not affect the strength of the timber, but that the mineral salts do, but chiefly in proportion to the quantity which is put in. That is, the copper salts and the zinc salts, which have to be put in, in large quantities, decidedly injured the tensile strength of the wood in all the cases that I know anything about. Injection of bichloride of mercury which, being

a very powerful antiseptic, is given in very much smaller doses to the wood, appears to have affected its strength very much less, so that a number of bridges which have been treated with corrosive sublimate have stood uncovered for from eighteen to twenty or twenty-five years in the eastern states; but I have always felt a dread of making timber brittle, and of having an accident by reason of the breakage of a chord or a stringer, and therefore I have always discouraged railroads from applying any of those mineral salts processes in timber, except for parts in compression. There, I think, it does not injure the strength.

Prof. J. B. Johnson—On what do you base these conclusions?

Mr. Chanute—Well, chiefly on what Mr. Lorenz, of the Philadelphia & Reading told me, and what Mr. Hinckley, president of the Philadelphia, Wilmington & Baltimore, stated as to his experience, and also upon the testimony which I gathered in 1882, 1883 and 1884 as to the failures of bridges and ties which had been treated with mineral salts. Those are set forth, I think, at some length in the report to the American Society of Civil Engineers in 1885; so I have always felt that I was between two pitfalls; on one side, if I did not put in enough of the antiseptic I was not doing my duty by the timber; on the other, if I put in too much, I might make the timber brittle and possibly lead to an accident.

Prof. Johnson—Do you know that actual tests were made, or is this just a kind of floating notion?

Mr. Chanute—It is the result of experiences as narrated to me by men to whom it occurred. For instance, Mr. Parker, who built the Philadelphia, Wilmington & Baltimore bridge at Havre de Grace, told me that the lower chords began to break within three months from the time he had erected that bridge; that he immediately put in iron clamps and eventually placed trestles under those spans, and that he narrowly escaped accidents a number of times. I know, of my own knowledge, from the master bridge builder of the Erie Railroad, that a number of bridges that were erected on that line had timber in them that had been burnetized at the company's own shops, and which proved to be exceedingly brittle and dangerous; that a hard, brittle crust outside, and rotten places inside, caused a number of them to break down. I know that the same thing occurred with some New England bridges; and, upon the whole, the result of the investigations made in 1882 and 1883 was that it was dangerous to use bridge timber that had been burnetized, because of its brittleness. Mr. Hinckley told me that some ties which he had taken special pains to have well treated, were so brittle that they broke in two upon being thrown off from a car onto the ground.

Prof. Johnson—That is good evidence, I should think.

Mr. D. W. Maher—I should like to ask Mr. Chanute if he has had any experience with treating wooden paving blocks with creosote, or other substances?

Mr. Chanute—No, sir, I have never had any, except this: Before I took up the process which I am now working on, which is that of chloride of zinc and tannin and glue, I went to St. Louis at the time that the floor of the St. Louis bridge was being renewed, which floor had been laid down seven years before with treated sweet gum blocks. The sweet gum is a wood, as Prof. Johnson will tell you, which will rot in eight months if given a good chance, and yet, after seven years, in the entire length of that bridge I could find only ten or twelve rotten blocks. All the rest were sound; but they had been worn by the wheels, and hoofs of the horses, to one-half their thickness. They were originally, I believe, five inches thick, but they had been worn to two and a half inches, so that the horses kicked them out with their hoofs, and therefore they had to be renewed. Now, in cases of that kind, where the traffic wears out the wood within the life of a durable wood it is not economical to treat it; it is better to buy the durable wood and lay it down in its natural state, because it is wear that is going to destroy it, and not decay.

Mr. Maher—You do not think the treatment affects the wear at all?

Mr. Chanute—No; the treatment does not materially affect the wear as against the wear of tires or horses' hoofs.

Mr. Maher—I understand the creosote people who treat block pavements claim that they not only preserve the wood but also add to the wear.

Mr. Chanute—That has to be tested by experience.

MONIER CONSTRUCTIONS.

E. Lee Heidenreich, M. W. S. E.

Read June 6th.

Up to about a year ago, Monier constructions were practically unknown in this country, while abroad they have gained a steadily increasing application in all branches of engineering.

However, with the unexpected increase in the cost of material and manufacture of steel structures, fortified concrete constructions have gradually attracted attention as a substitute for steel, and are, at present, approaching a universal recognition, also, in the United States. Owing to the very diversified applications of Monier construction, it would be impossible, in a short paper, to enter into details, and I shall merely explain its general construction, its principal qualities; and, by aid of illustrations, mention a number of instances where the Monier constructions have been successfully applied.

The Monier construction was originally invented by a French gardener, Jean Monier of Paris, and was preliminarily used in garden construction for fountains, flower pots, rustic benches, etc. Later, Monier commenced constructing water and gas reservoirs; and to-day there are over 1,000 water tanks built in Monier construction in France alone. Further applications in different directions resulted after Mr. G. A. Wayss of Berlin, in 1880, secured the patent rights for Germany, Austria and Russia, and formed the Central Technical Bureau in Berlin, with branches throughout Germany and the neighboring countries. Mr. Wayss applied the new construction not only for gas and water reservoirs, but also in house building, bridge building, hydraulic work, etc., and in 1887 wrote a book called "Das System Monier." The first edition of this book, which created quite a stir among engineers, was at once sold out and the book has not been in print since.

The royal architect in Berlin, Mr. Koenen, has further assisted in a prominent manner in the development and application of Monier construction—particularly by theoretically proving the stability of the construction and developing the mathematical formulæ for

calculations. The Central Technical Bureau in Germany has technical bureaus in Dresden, Hamburg, Hanover, Cologne, Koenigsberg, Leipzig-Plagwitz, Munich, Neustadt, Basel, Copenhagen, Denmark, etc.

The principle of the Monier system consists in a strengthening of cement mortar construction by the introduction of steel rods so located as to assume the principal tension or compression stresses in the structure, as the case may be.

For reservoirs for storage of water, grain, pulp, cement, etc., the horizontal rods placed in the cement mass, in annular or spiral rings, take the tension stresses; while the vertical rods, called distributing rods, assist in taking the vertical compression strains, and furthermore distribute tension stresses to the horizontal carrying rods. In arches, columns, culverts, etc., the carrying rods are placed to take compression, the mortar serving merely to prevent buckling, and I have explained the principle to many a layman by citing the following example:

If we place a ⅛-inch diameter rod, say 3 feet long, on end on the floor, and put a two pound weight on top, the rod will buckle; but encase the same rod in 4 or 5 inches of cement mortar, leaving 1-16 of an inch clear at each end, and you can load it with 150 pounds without trouble.

It is but natural that a number of variations in fortified cement constructions have sprung up since Monier's system became so widely known, for instance, the Wuensch, Moeller, Melan, Ransome, Hennebique and many others, but as Mr. David Molitor, Mem. Am. Soc. C. E., states in his paper on "Masonry Construction," in the January number of the *Journal of the Association of Engineering Societies:* "The Monier patent is so broad, embracing in a general way any iron parts enveloped by cement, that it is difficult to understand why all other systems are not infringements."

Mr. Edwin Thacher, Mem. Am. Soc. C. E., in his paper on "Concrete Steel Bridge Construction," in the *Engineering News* of Sept. 21, 1899, mentions the application of the Monier system for masonry arches, but considers the system too expensive, owing to the fact that all Monier arches, up to this time, have been built with one and three mortar, owing to the use of simple circular rods, while other systems, with more intricate sections of steel construction, can be built with say one, two and a half, and five concrete. This, however, does not change one of the principal advantages of Monier construction—its extreme simplicity and the ease with which the integral parts of the same can be obtained and transported. Mr. Thacher's very interesting paper goes into some of the details of the calculations of concrete steel constructions,

which I shall not repeat here, and refers to a number of experiments on Monier constructions made by the Austrian Society of Engineers and Architects in 1890, and by the well known German, Prof. Bauschinger; and I shall repeat some of the results found at this time.

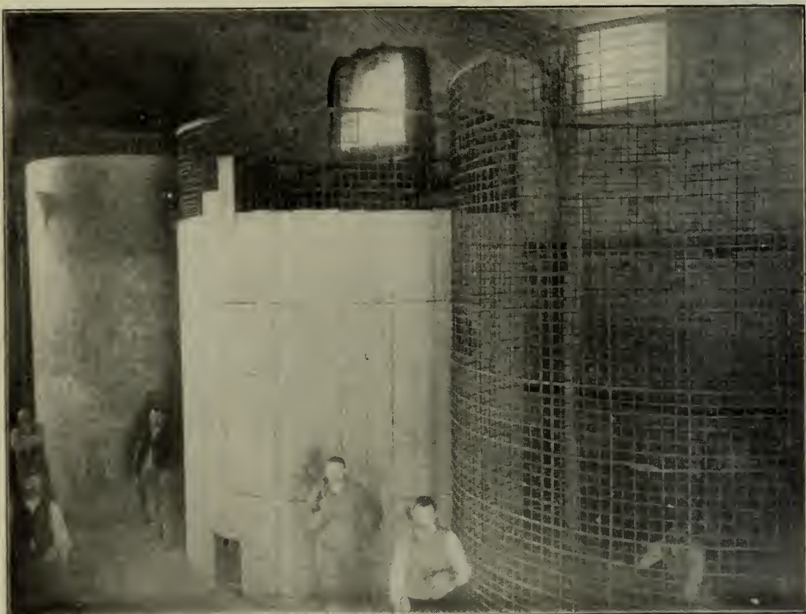


Fig. 1.—Monier Wine Casks

Elasticity:

The Austrian Society of Engineers tested a Monier arch 32.8 ft. span and 3.28 ft. rise, the crown being 7.87 thick, by loading one half of the span with 2,110 pounds per square foot, without any sign of failure, although the deflection was over 11 inches.

Expansion:

M. Benniceau, a French author, gives the thermic expansion of Portland cement 0.0000143 Celsius, while iron is 0.0000145.

Adhesion:

Prof. Bauschinger found the adhesion between the mortar and iron to be 570 to 640 pounds per square inch.

The Berlin Central Technical Bureau for Monier Constructions experimented with a wire 9-32 inches in diameter, imbedded in a baluster which had been exposed to the weather for ten years. An

FIG. 2.—Mold of First Monier Tank in the United States.

attempt to pull the wire from the concrete resulted in its rupture under a strain of 2,860 pounds. The great adhesion is attributed to a chemical connection between the silicates of cement and steel. Concrete as a preservative of Iron and Steel:

Fr. Von Emperger, Mem. Austrian Soc. Engineers and Architects, states that he knows of a case where iron rods were found practically rust free, having been imbedded in cement below water level for 400 years.

The Monier Company in Germany quotes a large number of instances where wires imbedded in concrete plates (Monier plates), which had been immersed in water or exposed to the air for years, not only did not exhibit signs of rust, but retained their original blue color, while the protruding ends of the wires were entirely eaten away.

After this preliminary description of the system, I shall proceed

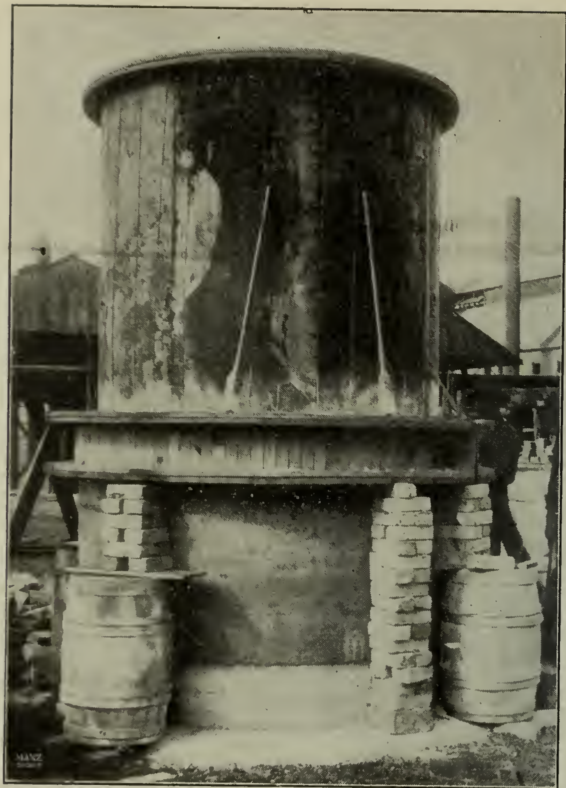


FIG. 3.—Tank Construction.

to enumerate some of the wonderfully diversified applications of the construction, and accompany some of the examples by illustrations:

(1) Construction of Reservoirs for Storage of Water, Wine, Oil, Pulp, Grain, Cement, etc.

Fig. 1 shows a photograph of three Monier wine casks; one showing the wire skeleton, one showing the wooden form against which the mortar is thrown and plastered from the inside, and one showing the finished tank.

Fig. 2 shows the mold of the first Monier tank built in the United States.

Figs. 3, 4 and 5 show plainly the modus operandi, and the next picture shows the four gentlemen making the tests, namely: L. Holmboe, engineer of construction, Illinois Steel Co.; F. Gasche, mechanical engineer, Illinois Steel Co.; John Jones, concrete contractor, Illinois Steel Co.; E. Lee Heidenreich.

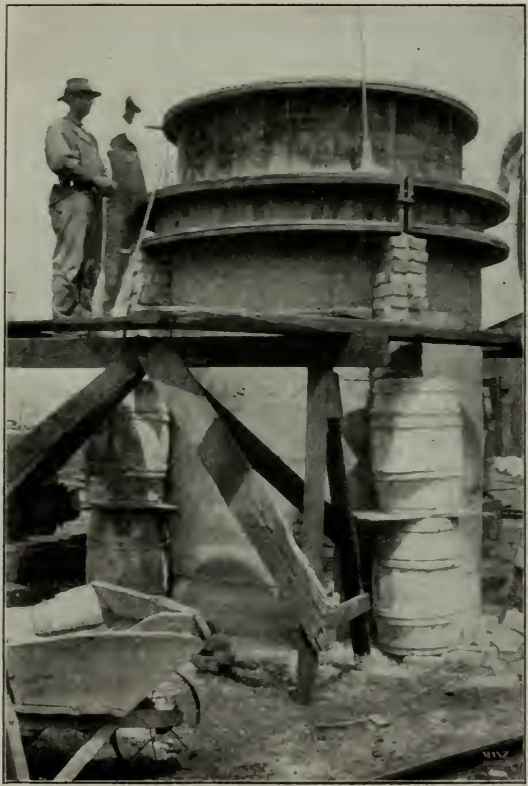


Fig. 4.—Tank Construction.

Figs. 7 and 8 show the application of Monier tanks for storing 500,000 bushels of grain, as designed for the Illinois Central R. R. Company at New Orleans, La. The entire structure is one monolithic mass; the spaces between the tanks also being utilized for grain storage. The roofs considered as top chords, floors as bottom chords and bin walls as panel construction, it is obvious that any settling in the foundations under uneven load is almost impossible if the total supporting area is sufficient.

About a month ago I was on top of a 20 foot diameter by 66 foot high tank, in Minneapolis, built and tested last fall; and now they are adding another 60 feet in height, making it 126 feet high. I did, for over four years, try to induce the owner to build Monier tanks instead of wooden or steel bins, and submitted designs, estimates, and reports without number. He finally sent some member of the firm to Europe to investigate the system, and is now building thirty tanks in Duluth, with a total capacity of 3,750,000 bushels of grain.

FIG. 5.—Tank Construction.

FIG. 6.—Making Tests.

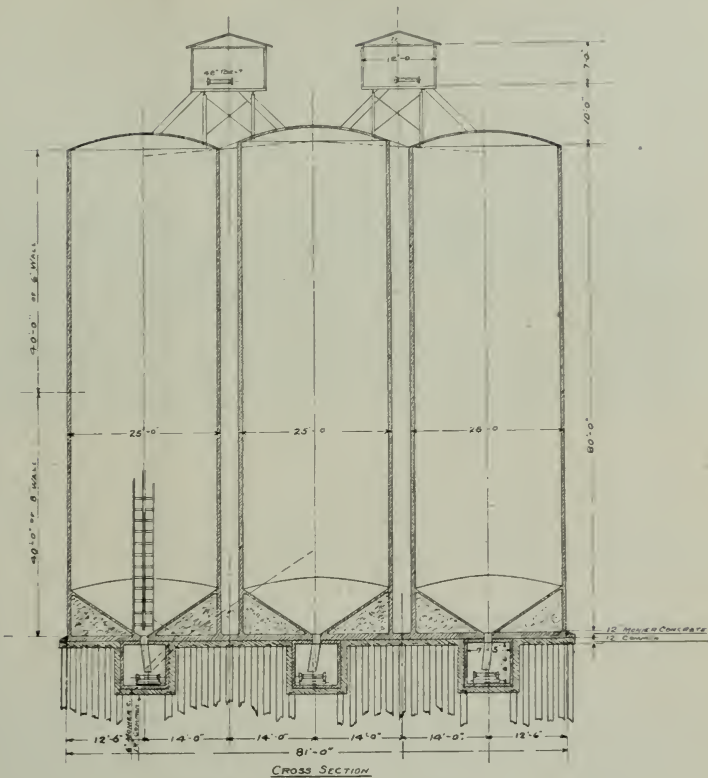


Fig 8.—Monier Grain Tanks.

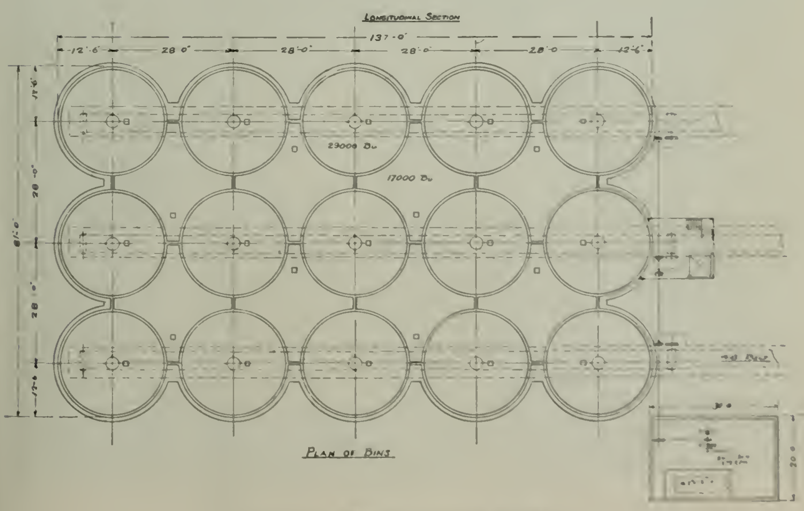


Fig. 7.—Monier Grain Tanks.

Fig. 9a.—Monier Grain Elevator.

Fig. 9 shows the railway tank constructions. The elevated tanks are, of course, quite expensive; while the settling tanks cost less than two cents a gallon capacity.

Figs. 9a and 9b show two 1,000,000 bushel grain elevators, built

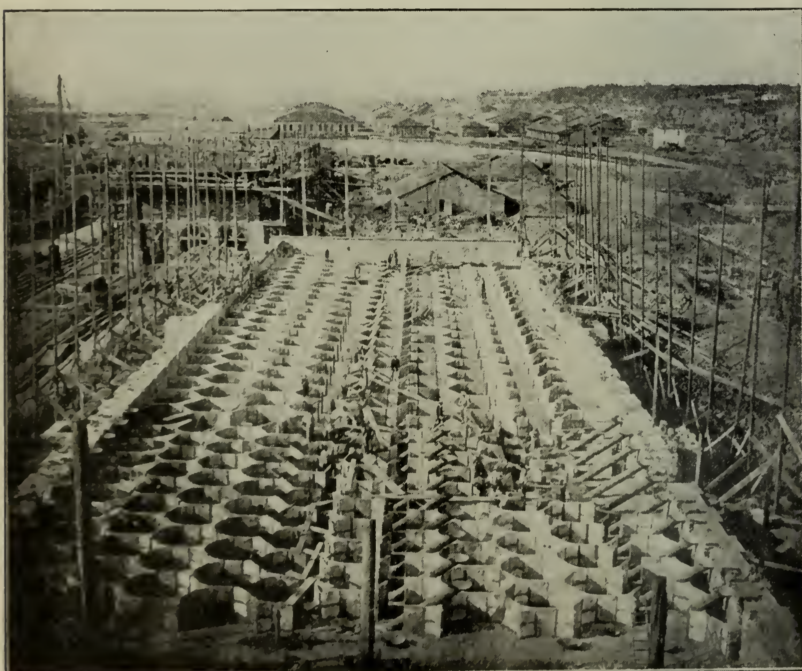
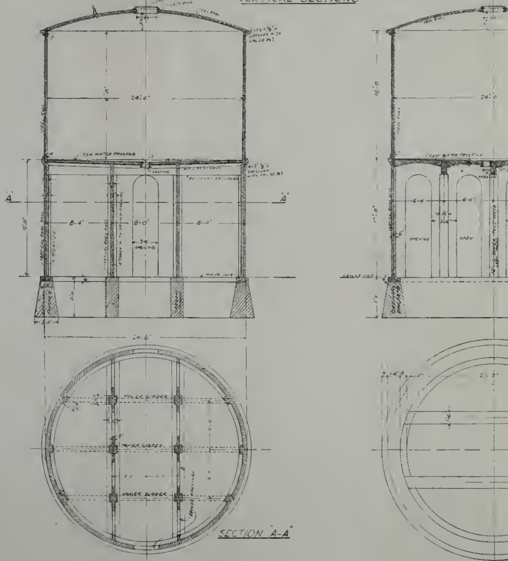


Fig. 9b.—Construction of Monier Grain Elevator.

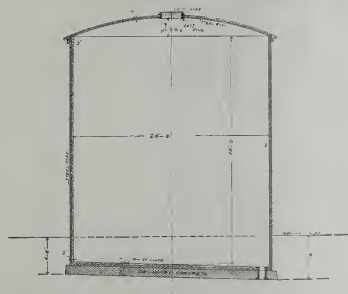
Western Society of Engineers
Vol. V. No. 3.—Fig 9.
Heidenreich—Monier Constructions.

RAILROAD WATER TANK 54000 GALS

VERTICAL SECTIONS

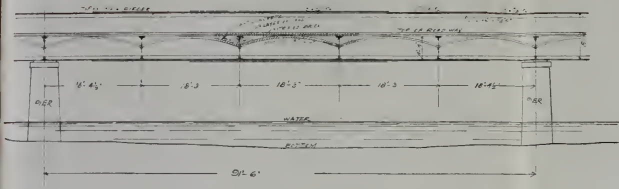


RAILROAD WATER TANK 35000 GALS



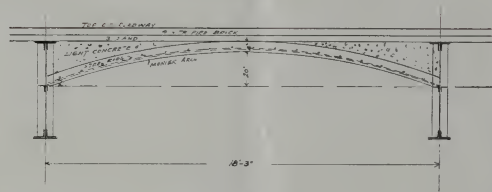
LONGITUDINAL SECTION OF ONE SPAN

1/8" SCALE



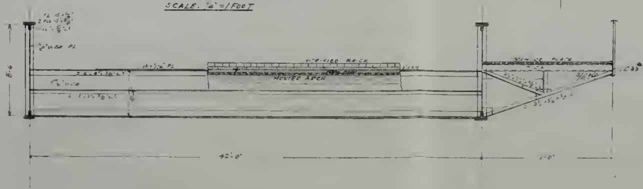
SECTION OF ONE ARCH

SCALE 1/2" = 1 FOOT



CROSS SECTION OF ROADWAY

SCALE. 1/4" = 1 FOOT



Design for Chicago Street Bridge, Elgin Ill.

NOTE.—Steel angle, plates, etc., may be substituted by other sizes of equal strength.

at Galatz and Bralia, Roumania. Here the bins were hexagon and built of Monier plates, made on the ground and set up like tile walls.

(2) Bridges, and Preservation of Steel in Bridges and Viaducts.

Fig. 10 shows a design for the substitution of Monier plates for buckle plates, as submitted to Mr. E. B. Guthrie, chief engineer of the Grade Crossing Commission in Buffalo, and also of Monier plates for protecting the under side of a viaduct from corrosion on account of fumes and gases from locomotives, and from the effects of the weather. Aside from a saving of 50 per cent in cost, as between a ⅜-inch buckle plate and a Monier plate, the capitalization of the cost of scraping and repainting the steel and wooden ceiling will prove the superiority of Monier constructions, from an economical standpoint, at a glance. It goes without saying, that the methods of applying Monier plates to existing or new structures can be varied ad libitum. In highway bridge construction the longitudinal floor beams are omitted and Monier arches carried, in 12 to 16 foot spans between the transverse girders, reaching from truss to truss (Fig. 11).

Fig. 12 shows a bridge at the Bremen Exposition. This bridge,

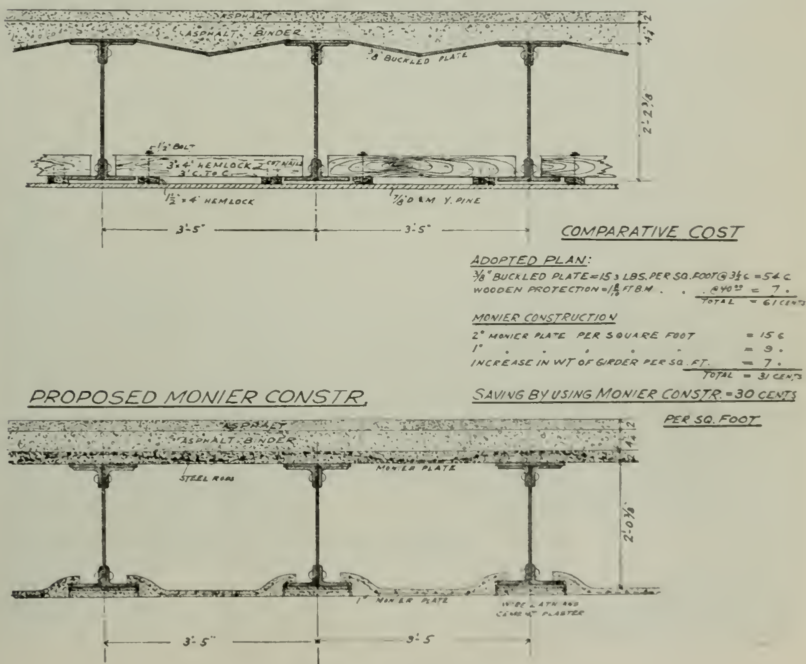


FIG 10 —Monier Bridge Plates

which was intended merely as a temporary affair, spanned one of the lagoons in the exposition parks. It was figured for a live load of 200 pounds per square foot, with factor of safety of 6. The width of the bridge was 10 feet in the middle and 26 feet at the abutments. The span was 131 feet and the spring of arch 14 feet 9 inches. The thickness of concrete at the crown was 10 inches, and 22 inches at the abutments. The bridge was left standing for one year.

(3) *Buildings, Floors and Partitions.*

I shall confine myself to a few instances. Fig. 13 shows a 16 ft. span for warehouse or packing house construction, where the floor beams are done away with and the arches carried from girder to girder. The arch has a dead load of 80 pounds and a live load of 250 pounds. It is 1¾ inches thick in center and 2 inches at the skewback.

Figs. 14, 15, 16 and 16a explain themselves.

I will call your attention to Figs. 16 and 16a, showing how to do away with I beams in a pinch if the mill is behind time and you cannot wait. Simply use a Monier girder with a rod or two at the top for compression, and a rod or two at the bottom for tension.

Fig. 12.—Bridge at the Bremen Exposition.

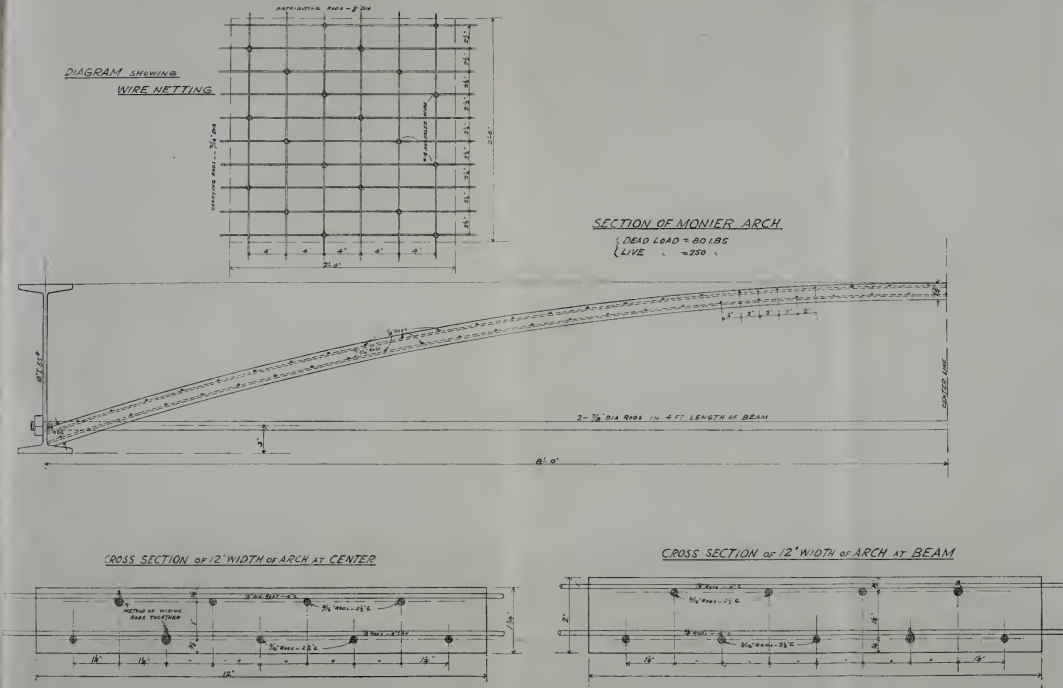


DIAGRAM SHOWING
WIRE NETTING
2'-0"
SECTION OF MONIER ARCH
DEAD LOAD = 80 LBS
LIVE " =250 "
2– 7/8" DIA RODS IN 4 FT LENGTH OF BEAM
8'-0"
CENTER LINE
CROSS SECTION OF 12" WIDTH OF ARCH AT CENTER
METHOD OF WIRING RODS TOGETHER
12"
CROSS SECTION OF 12" WIDTH OF ARCH AT BEAM

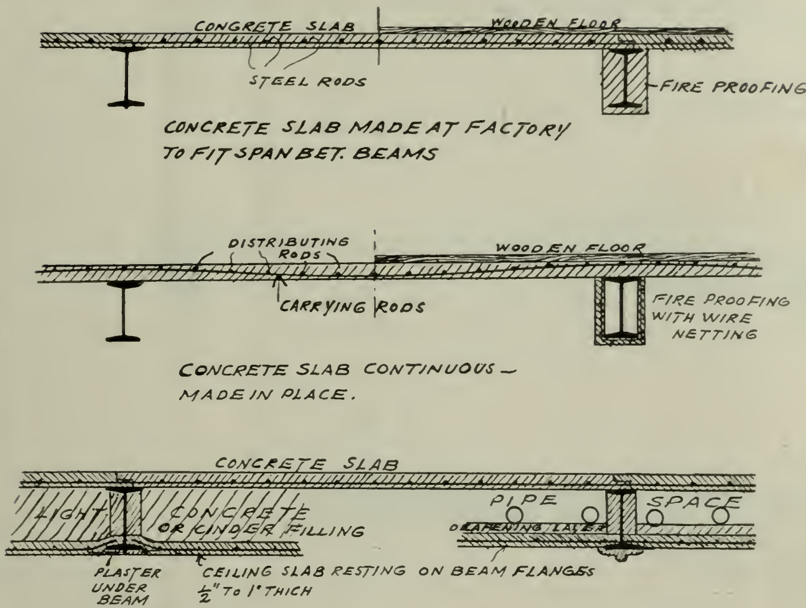

CONCRETE SLAB
WOODEN FLOOR
STEEL RODS
FIRE PROOFING
CONCRETE SLAB MADE AT FACTORY
TO FIT SPAN BET. BEAMS
DISTRIBUTING RODS
WOODEN FLOOR
CARRYING RODS
FIRE PROOFING WITH WIRE NETTING
CONCRETE SLAB CONTINUOUS—
MADE IN PLACE.
CONCRETE SLAB
LIGHT CONCRETE OR CINDER FILLING
PIPE SPACE
DEAFENING LAYER
PLASTER UNDER BEAM
CEILING SLAB RESTING ON BEAM FLANGES
½" TO 1" THICK

FIG. 14.

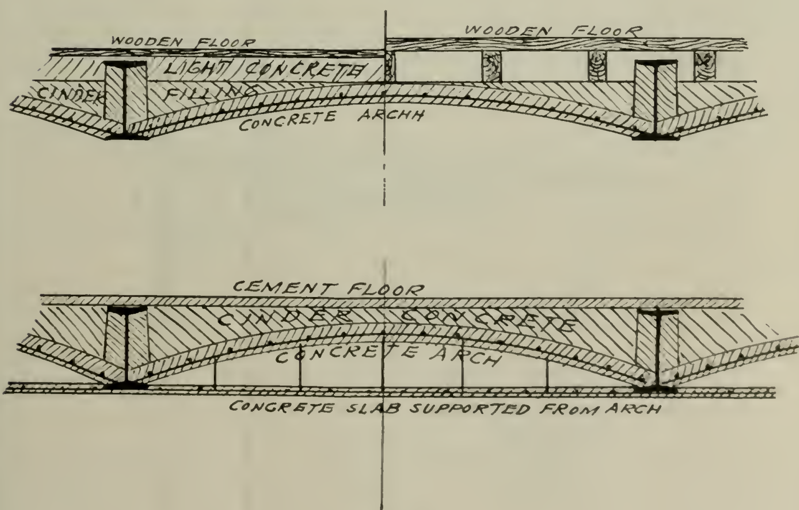
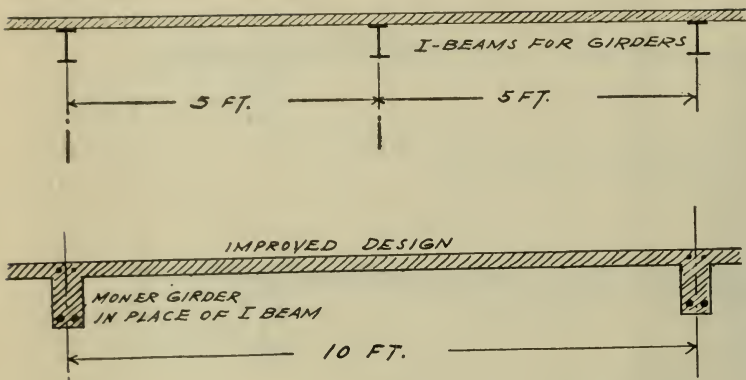

WOODEN FLOOR
WOODEN FLOOR
LIGHT CONCRETE
CINDER FILLING
CONCRETE ARCH
CEMENT FLOOR
CINDER CONCRETE
CONCRETE ARCH
CONCRETE SLAB SUPPORTED FROM ARCH

FIG. 15.



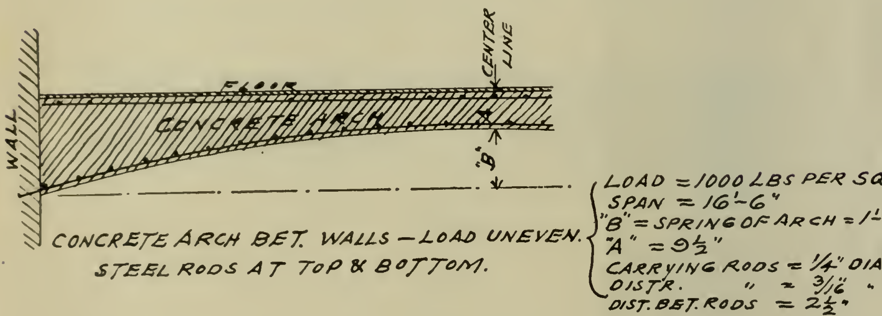


FIG. 16.

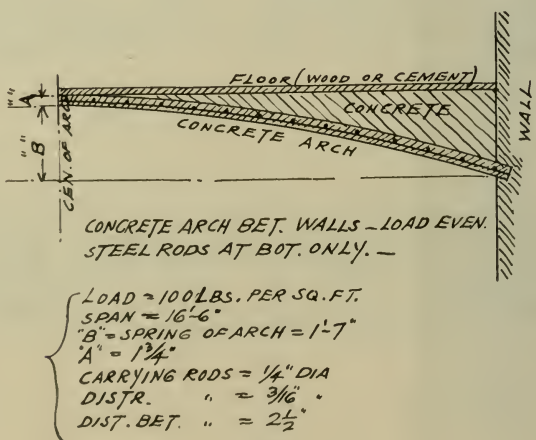
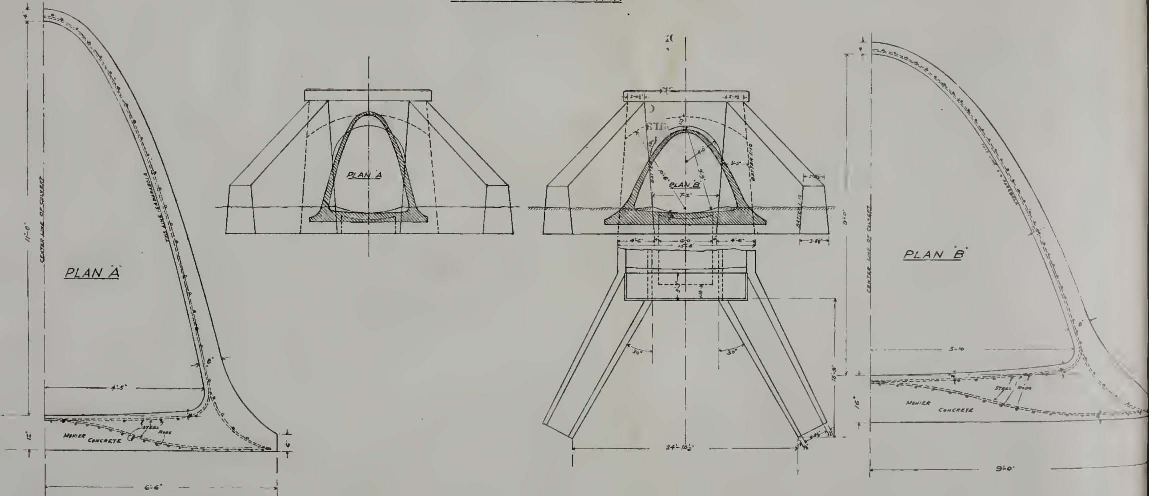
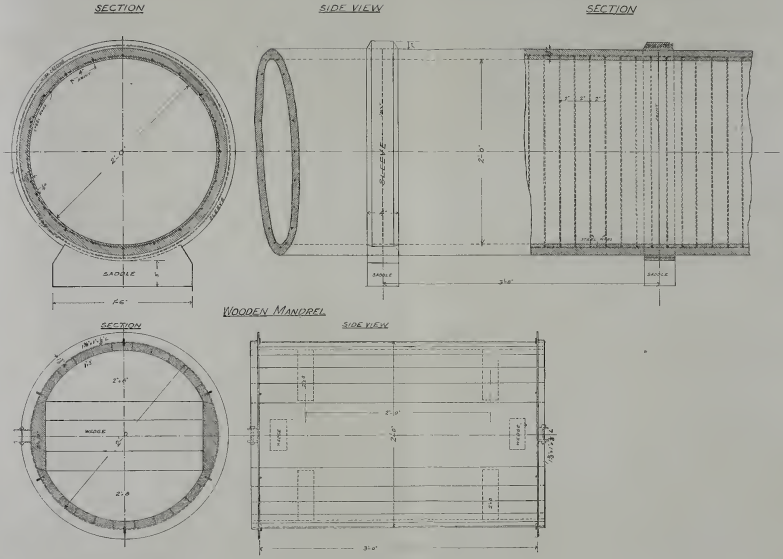


FIG. 16a.

CULVERTS IN MONIER CONSTRUCTION
AS ADAPTED TO
ILL. CENTRAL RAILROAD CO'S.
STANDARD 8 FOOT ARCH





NOTE.

Cost of 24-inch Monier culvert, laid, $2.50 per lin. foot.
Cost of 24-inch cast iron pipe (medium), laid, $3.67 per lin. foot.
Weight of Monier culvert, 100 lbs. per lin. foot (incl. saddle and sleeve).
Weight of cast iron pipe, 245 lbs. per lin. foot.

Cost of 30-inch Monier culvert, laid, $3.00 per lin. foot.
Cost of 30-inch cast iron pipe (medium), $5.00 per lin. foot.
Weight of Monier culvert, 145 lbs. per lineal foot.
Weight of cast iron pipe, 335 lbs. per lin. foot.

Cost of 36-inch Monier culvert, laid, $3.50 per lin. foot.
Cost of 36-inch cast iron pipe (medium), $6.80 per lin. foot.
Weight of Monier culvert, 195 lbs. per lin. foot.
Weight of cast iron pipe, 450 lbs. per lin. foot.

Cost of 42-inch Monier culvert, laid, $4.50 per lin. foot.
Cost of 42-inch cast iron pipe (medium), $8.85 per lin. foot.
Weight of Monier culvert, 270 lbs. per lin. foot.
Weight of cast iron pipe, 590 lbs. per lin. foot.

Samples of Monier girders may still be seen at Jackson Park at the old exhibit of the Monier company, showing a few Monier plates and girders, and a Monier stairway and platform. The great fire that destroyed the "White City" failed to have any effect on this little exhibit which now remains there simply defying time and awaiting a slump in the dynamite market. However, the foundations for the supports of the Monier plates and girders are wood and considerably decayed, so it will be but a matter of time before the plates and girders will be lying on the ground.

(4) *Culverts and Flumes.*

Fig. 17 shows a culvert construction resting on rock, one of the largest culverts on the Venezuela Railway. The cross section is here, as in all the culverts and tunnels of said railway, elliptic. The thickness at the top is only $6\frac{1}{4}$ inches (16 centimeters).

Fig. 18 shows a comparison between an 8 ft. standard concrete culvert for the Illinois Central Railway Co. and a Monier culvert of either flat or high cross section, both being constructed on a parabolic curve. The saving in cost is about 25 per cent; but the main advantage is the elasticity of the Monier culvert, as compared with the heavy concrete culvert, in the unavoidable settlements which take place on high embankments, the small dimensions of the walls preventing the cracking so common in concrete construction, and the steel rods taking care of the tensions occurring under accidental and extraordinary loads.

Fig. 19 shows pipe culvert construction, with a list of prices and weights as compared with cast iron pipe; and when we take into consideration that a Monier culvert can be transported in its inte-

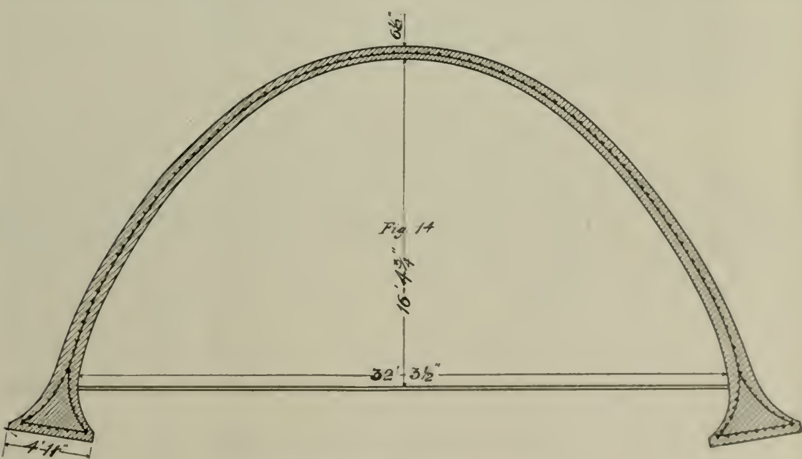


Fig. 17.—Culvert Construction.

gral parts and built on the premises, while the cast iron culvert must be hauled in a finished condition ahead of the railway work, railway engineers and contractors will readily appreciate the value of Monier pipe. The Chicago, Rock Island & Pacific Railway has been experimenting considerably with concrete pipe culverts, but the advantage of a Monier pipe is obvious, owing to its elasticity during the settling of embankments. Monier pipes may be built in place in one continuous length; but during the past few years they have been built at pipe yards, the same as sewer and cast iron pipes, and transported.

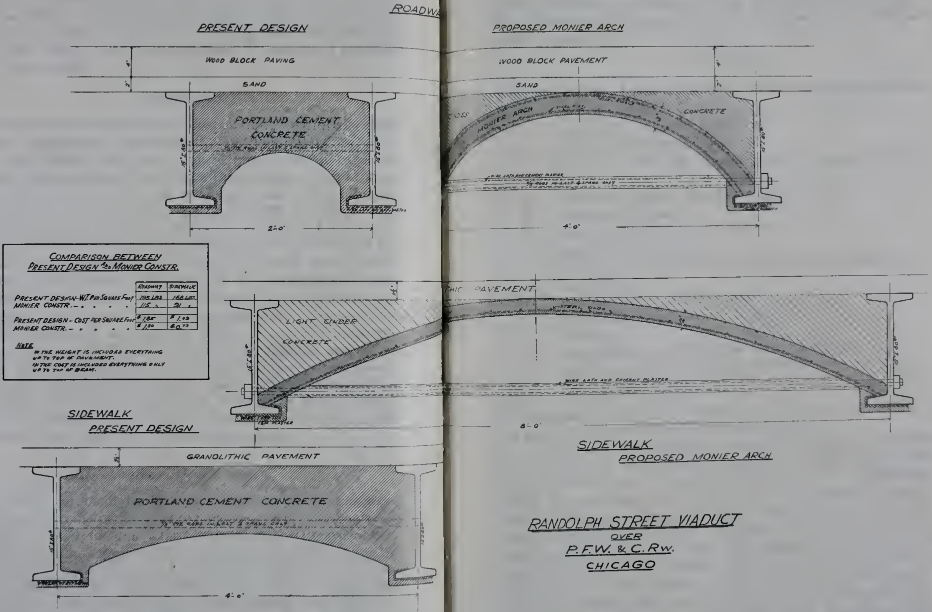
(5) *Fortifications.*

In Germany and Austria, Monier constructions are rapidly gaining extensive application in permanent, as well as temporary, fortifications. For instance, they have shown themselves an excellent construction for bomb-proof vaults to withstand the action of modern projectiles, such as torpedo or mine grenades. The different experiments were commenced near Berlin in 1888, and have been kept secret, so the details are unknown. However, I know that the Monier vaults which have been fully sufficient to withstand the action of torpedo projectiles have a span of 5 meters and a rise of 10 per cent, and only had a thickness of 20 centimeters, or less than 8 inches. The Monier vault was covered with concrete, but in such manner that a layer of sand was introduced between the arch and the concrete to increase the elasticity and distribute the blow. The thickness of the layer of sand was .6 meter and of the concrete .9 meter. This Monier arch, with 5 meter span, proved to carry 10,000 kilograms per square meter with a safety of 10. The Emperor of Austria has given Mr. Wayss, the Vienna representative of the Monier construction there, the sole right of constructing bomb-proof vaults for the Austrian empire.

Miscellaneous Applications.

In the drainage problem in New Orleans, several designs were submitted for the roofs of the covered canals. Fig. 20 shows the design finally adopted for the Third street canal. It consists of a 2-inch plank platform, supported by means of beams and posts on the bottom of the canal; 20 inch I beams are placed 4 feet from centers; 3 inches of concrete are laid on the platform; expanded metal is placed on the lower flange of the beams; then comes 4 inches of concrete, and then the beams are covered up as shown, giving a total dead load of 275 pounds.

Through our Southern Technical Bureau at New Orleans we submitted the design shown in Fig. 21, giving a dead load of 150


ROADWAY
PRESENT DESIGN
WOOD BLOCK PAVING
SAND
PORTLAND CEMENT CONCRETE
15" I 80#
2'-0"
PROPOSED MONIER ARCH
WOOD BLOCK PAVEMENT
SAND
MONIER ARCH
CONCRETE
4'-0"
COMPARISON BETWEEN PRESENT DESIGN AND MONIER CONSTR.
ROADWAY | SIDEWALK
PRESENT DESIGN-WT. PER SQUARE FOOT 195 LBS 168 LBS
MONIER CONSTR. 115 91
PRESENT DESIGN - COST PER SQUARE FOOT $1.85 $1.03
MONIER CONSTR. $1.30 $0.73
NOTE
IN THE WEIGHT IS INCLUDED EVERYTHING UP TO TOP OF PAVEMENT.
IN THE COST IS INCLUDED EVERYTHING ONLY UP TO TOP OF BEAM.
SIDEWALK
PRESENT DESIGN
GRANOLITHIC PAVEMENT
PORTLAND CEMENT CONCRETE
4'-0"
LIGHT CINDER CONCRETE
PAVEMENT
STEEL RODS
WIRE LATH AND CEMENT PLASTER
8'-0"
SIDEWALK
PROPOSED MONIER ARCH
RANDOLPH STREET VIADUCT
OVER
P.F.W. & C.Rw.
CHICAGO

pounds and enabling us to place the beams 5 foot 6 inch centers. In the 7,300 foot section, already contracted for, we could effect a saving of about $60,000; and I dare say you will agree with me that the Monier design is the more professionally rational of the two—placing concrete in compression instead of in tension.

Fig. 22 shows our design for the Randolph street viaduct over the Pennsylvania Railroad tracks, as a comparison with the present design submitted.

In General.

Before closing, I will repeat some of the principal advantages of Monier construction. They are:

1. Durability—will last centuries.
2. Absolutely fireproof.
3. Maximum carrying capacity, with minimum weight of structure.
4. Resistance against shocks or vibrations.
5. Economy of space.
6. Saving in tie rods and anchor rods.
7. Rapid construction.
8. Cleanliness; absence of organic matter in materials.
9. Cheapness.
10. No expense for maintenance.
11. Absolutely air and water tight.
12. Dryness.
13. Adaptability to all possible forms or shapes.
14. Safety against thieves and enemies.
15. Reduction of insurance.

Referring to item 1—"Durability:" I think this can be taken as granted from what has been stated before.

As to item 2—"Absolutely fireproof:" I have a large number of examples of the fireproof quality of Monier construction, but time permits me to mention only one. On November 20, 1886, an experiment was conducted near Cologne, at a rubber factory, to compare corrugated iron construction covered with concrete, with Monier arches. The span in both of them was 4.28 meters with 10 per cent rise. The Monier arch was 4½ centimeters thickness, or 1¾ inches. The load on both amounted to 410 kilograms per square meter. Under both arches was made a fire about 30 inches below the skewbacks. The corrugated iron was red hot in a few minutes, and the floor fell after twenty minutes' time; while the Monier arch remained intact, although the fire was maintained a long time and was followed by pouring cold water on the same. The fire underwriters in Berlin, Germany, have de-

clared Monier constructions absolutely fireproof, and so consider them in their insurance arrangements.

Items 3, 4, 5 and 6 speak for themselves.

Regarding item 7—"Rapid construction:" The saving of time is often of the greatest moment to the engineer as well as the contractor. Owing to the slight dimensions of Monier arches as compared with common concrete arches, they dry far more rapidly and assume their full strength in a fraction of the time required by the concrete arches. In railway construction, a series of Monier bridges and culverts from 20 to 30 ft. span have been known to be completed in about one day each.

Of the other items I will mention only item 10—"No expense for maintenance:" This is is one of the principal advantages in the use of Monier construction as a preservative for existing viaduct or bridge construction. The expense of maintaining the viaducts and overhead crossings in the city of Chicago alone, if capitalized, would represent a large sum of money, which will be entirely saved at the adoption of Monier construction instead of buckle plates and floor beams.

In conclusion, I will say that the Monier system has so many applications that it might be a subject for a book the size of Webster's dictionary; but my purpose is merely to bring the matter to the attention of the engineering fraternity in a general way. The application of the Monier system for sewers, water-ducts, flumes, tail-races and irrigation purposes represents a large and interesting field of engineering improvements; and the use of the system as water and rust-proof bunkers in marine engineering may be mentioned as another market; and, while I have made the Monier system a study for a number of years, I find that the more I know of it, the more astounded I am at its stupendous possibilities.

WRITTEN DISCUSSION.

Mr. H. W. Parkhurst—During the past four years the Illinois Central Company has spent upward of $300,000 in constructing about 55,000 cubic yards of concrete masonry, most of which has been done under the immediate direction of the writer.

The above amount covers the following different kinds of work:

Parapet or head walls for cast iron pipe culverts, ranging in size from 2 feet up to 6 feet in diameter.

Concrete arch culverts, ranging in size from 5 feet to 20 feet span.

Abutments and piers for the support of I beam and plate girder spans, varying from 10 feet to 75 feet.

Rebuilding and repairing stone masonry in various stages of decay, including re-enforcing and jacketing of arches of 40-foot span, abutments for double track bridges, etc.

In a number of cases, where full-centered semi-circular arches could not be adopted on account of the clear height under the track, the writer has used a combination of iron and concrete, in which, however, the iron was generally sufficiently strong to carry the loading, and the concrete was put in as a protection to the same, with a view of making an imperishable structure.

Within the past three months one culvert of 24-inch pipe of "Monier" construction has been constructed for us by the New Orleans agents of the "Central Technical Bureau," having control of the "Monier" patents in this country.

This culvert is under a bank some 14 to 16 feet in height, and is about 65 feet in total length, and is provided with concrete end walls, built in the same style as for cast iron pipe culverts; that is-heavy walls, substantial enough to withstand the thrust of the em, bankment, by virtue of their mass.

The writer regards the use of the "Monier" system for culverts, arches, etc., as, in a sense, *experimental,* inasmuch as neither of the two materials employed (steel, or iron, and concrete) is in sufficient quantity to be durable without the aid of the other. Any defect in the concrete will result in an erosion of the metal, and the consequent failure of the structure. For that reason the writer would advocate only a cautious use of this method of construction.

There is, apparently, no present *economy* in the substitution of "Monier" pipe culverts in place of cast iron pipe culverts, since the price of the one does not differ materially from the other. The iron pipe culvert could be constructed much more rapidly than the "Monier" pipe; and, within reasonable limits as to size, there is little doubt of the durability of the pipe; whereas, for reasons already expressed, there is a doubt as to the permanency of the "Monier" construction. The resistance to distortion in the latter

method of construction is undoubtedly much less than in the case of the cast iron pipe, and, if the concrete should once be cracked, so that moisture has access to the metal, the durability of the "Monier" culvert would be materially lessened.

Mr. Ralph Modjeski—Mr. Heidenreich's very interesting paper would have been still more interesting and valuable had he given us a more complete explanation and discussion of the principles of steel concrete construction in general, and the Monier construction in particular. The subject is a comparatively new one, and one of great importance and interest to the engineering profession, and therefore deserves to be discussed at length. Perhaps the author of to-night's paper might be induced to come again before the Society with a more extended treatise on this important subject, giving formulæ, tables, diagrams, etc., etc.— all things which engineers delight in.

Mr. Heidenreich describes only one particular system or method, which bears the name of Monier. There is no doubt that this system has been very extensively, though by far not exclusively, used abroad and in the United States, and that it has given excellent results. There are many other systems of steel concrete construction, however, all of them claiming advantages of their own, and many of them having such advantages. I will mention here the following: System Bordenave, Hyatt, Ransome, Melan, Cottancin, Hennebique, Bonna, etc.

The name of Monier applies principally to that system of construction which consists in imbedding in the concrete two series of parallel steel or iron rods which intersect at right angles. The rods are brought into contact and a wire is wound around each intersection. According to the duty imposed on each layer of rods they are called, as Mr. Heidenreich states in his paper, distributing or carrying rods. The section of the carrying rods varies with the stress which they have to sustain. They are generally spaced from two to four inches on centers. The distributing rods are generally from ⅛-inch to ¼-inch in diameter. Each carrying rod is generally of one piece, from support to support, while the distributing rods may be of shorter overlapping pieces. The wire used for tying intersections is generally 3-64 inch to ⅛-inch in diameter. Two or more layers of cross wires may be used if stability requires it.

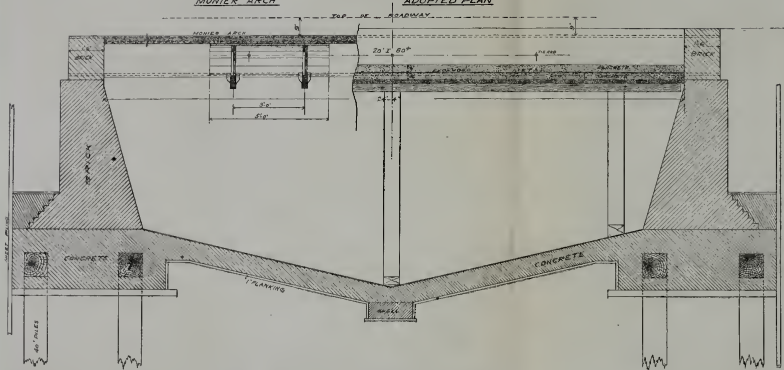
The Bordenave system consists in the substitution of small sized shapes, such as channels, angles or I beams, of steel for rods. These shapes are of very small dimensions. They offer the advantage of greater rigidity during construction.

The Hyatt system consists in a skeleton of flat parallel bars

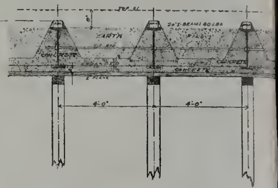
WESTERN SOCIETY OF ENGINEERS.
Vol. V, No. 3.—FIGS. 20 and 21.
Heidenreich—Monier Constructions.

CROSS SECTION

MONIER ARCH | ADOPTED PLAN



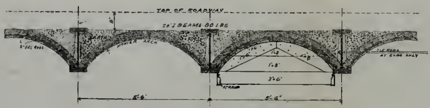
LONGITUDINAL SECTION—ADOPTED PLAN



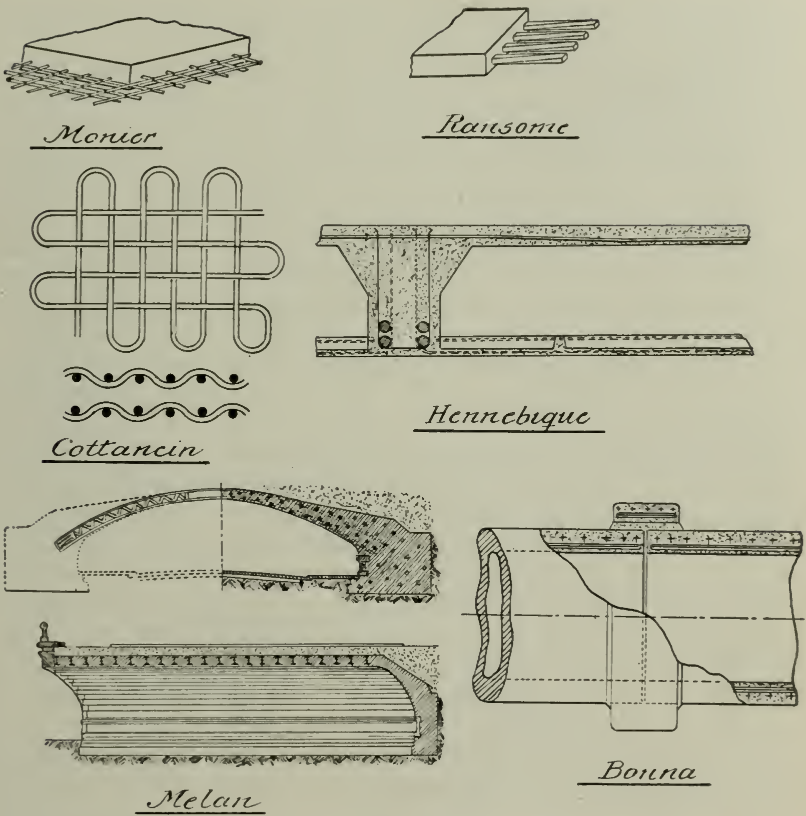
NOTE.—Cost of "adopted plan" over and abo
"Monier Construction" $8.00 per lineal foot of can

Dead load per sq. ft., "adopted plan" 275 lbs.
Dead load per sq. ft., "Monier Construction" 150 l

LONGITUDINAL SECTION—MONIER ARCH



PLAN SHOWING COVERING OF 3RD STR. CANAL
NEW ORLEANS, LA



Some Systems of Steel Concrete Construction.

placed vertically, and horizontal rods running through holes punched in the bars.

Most of us are familiar with the Ransome system, which consists of twisted square bars imbedded in concrete.

The Melan system finds its principal application in arches where curved I beams or built beams are imbedded in concrete.

In the Cottancin system the wires, generally 3-16 inch diameter, are woven into a netting, the mesh of the netting being made smaller or larger, according to strength required. No tying wires are used at intersections, as the bends in the wire netting prevent their slipping.

The Hennebique system, which is used very extensively in France, has its principal application in floors of buildings, partitions, etc. The rods used here are much heavier than in the Monier system. Two or more of the rods are placed lengthwise

near the bottom of the concrete beam, and are tied to the upper portion of the beam and to the floor slabs by thin vertical bars.

Mr. Bonna uses small steel rods of cross-shaped section. He has recently constructed about 25 miles of sewer pipe, varying in diameter up to 5 feet 11 inches, with pressures reaching 60 pounds per square inch; also a water pipe at Nimes of 3 feet in diameter for a head of 143 pounds per square inch. The pipes for pressures exceeding 25 to 30 pounds have been provided with an inner shell of steel plate. There seems to be a limit as to pressures which an ordinary concrete pipe with steel skeleton can support without seepage. This limit is about 30 pounds per square inch. It is quite necessary in steel concrete pipes to increase the head gradually; at first the seepage is considerable, but gradually it becomes less and less pronounced, until it ceases completely under full pressure.

Mr. Heidenreich enumerates all advantages of steel concrete construction. Most of them are certainly very important. It might be well to mention a few disadvantages. The principal one is the uncertainty of calculations which have to deal with a material of such variable resistance as concrete. The formulæ used in these calculations are mostly empirical. By reason of this uncertainty, an excess of material is generally used and the theoretical economy cannot be realized. I will say, however, that as experiments are being made from day to day this uncertainty gradually disappears, and even now, in many cases, steel concrete construction is considerably the most economical. Another disadvantage at present is, that no engineer feels free to design a piece of work without being in danger of infringing some patent. Fortunately for many engineers, the patents apply to the special forms of the steel skeleton, which is thoroughly imbedded in concrete and cannot be seen after the work is completed.

Mr. J. B. Johnson.—The writer welcomes every proper form of popularization of engineering and architectural constructions in cement and steel in combination. But he thinks it will greatly advance the practice of this new system if it is relieved from the burden of a proprietary name and from the suspicion of being a patented system. It can be easily shown that anyone is at liberty to employ steel and concrete in combination in almost any way he chooses, without infringing any fundamental patent. There are a few patents upon particular combinations of steel and concrete which may be made to hold, but these can be avoided if one so desires.

As to Monier's claims, they seem to the writer to be practically nil, so far as priority of use is concerned. Neither does it appear that any American patent on this system has ever been taken out.

It seems that Mr. W. E. Ward, M. Am. Soc. Mech. Engrs., of Port Chester, N. Y., was the first to use iron or steel in combination with concrete in a thoroughly scientific manner. In a paper before the Am. Soc. Mech. Engrs. at the Cleveland meeting, in June 1883, Mr. Ward described at length the construction of a residence wholly of reinforced concrete, which he designed and built in 1875.* He says he began his experiments to this end in 1871, and began planning for these in 1867. He claims the "invention" of this system of construction but has freely given it to the public, apparently never having applied for a patent upon it. In France, letters patent were granted in 1869 to Francois Coignet on a "Combination of Iron and Concrete," so that Monier's use of wire netting in concrete for the manufacture of large vases (for orange trees) and small tanks, in 1876, loses all significance. Furthermore, Monier was a gardener and used his wire netting in the body of his concrete merely to bind it firmly together and to prevent cracking. He had no knowledge of the stresses in a beam, and the use of the iron to resist the tensile stresses while the concrete is relied on to resist the compressive stresses. Thaddeus Hyatt, also, in his work on "Concrete-Iron Construction," 1877, reports tests made for him by Kirkaldy, London, in 1876 and 1877. Both Hyatt's book and Ward's paper seem to have dropped out of notice. Hyatt seems never to have heard of Monier. It is Ward in America and Hyatt in England, therefore, to whom credit is due for a scientific combination of these materials. Hyatt acknowledges that the combination is not new, but claims that these two materials had not previously been intelligently combined in building construction.

The reason this system came to bear Monier's name is because it was patented and exploited in France and Germany under this name, and has now been brought here from Germany. The Monier construction, proper, seems to be adapted only to circular tanks and to arches symmetrically loaded. Where bending moment has to be resisted, the adaptation required is so different from the true Monier (imbedded wire) construction that it should no longer bear his name. It should more properly be called cement-steel, or steel-cement, construction. When plain wires or rods are used, reliance being placed solely upon the adhesion of the concrete to the wires, they are sure to work loose if there is much jar or variation of stress. I have been told that this has been the case in the Studebaker building, Chicago, to such an extent as to necessitate the replacing of floor systems. The construction is similar to that shown in Fig. 14, page 219. The steel bars should

* See Proc. Am. Soc. Mech. Engrs., Vol. IV, page 388.

be twisted, as in the Ransome construction, or better, they should be crooked or grooved so as to take a firm hold of the concrete. Where cement mortar alone is used the adhesion to plain wires will be sufficiently high to warrant the use, but in concrete the adhesion to plain surfaces will be found insufficient.

As to this construction being "absolutely fire proof," it is difficult to see how it can be any more fire proof than the concrete of which it is composed. If this concrete material be a cement, mortar and crushed stone or gravel, it is far from being "absolutely fire proof."

ORAL DISCUSSION.

The illustrations of Mr. Heidenreich's paper were commented on by him as follows :

Fig. 2—The center part shows the interior mould, and below here we see the outer form in two halves, which was raised during construction. It shows the distributing rods plainly stretched from the top of the inner form to the bottom of the same. The carrying rods are not shown on this picture. They will be shown on a later one.

Fig. 4—Shows the tank built to within eighteen inches of the top. The tank was completed within five hours. This shows the carrying rods tied every third and fourth intersection to the distributing rods by means of annealed wire.

Fig. 5—Shows a tank built of steel Portland cement at the Illinois Steel Company's yards at South Chicago. It has been there about two years, and at times filled with water. Major Marshall, who visited the works some time ago, stated that he considered this Monier tank the finest piece of concrete work he had seen at the steel works.

Fig. 9—It is here designed to carry the entire tank on Monier construction, consisting of Monier columns resting on concrete foundations. The tanks, as you perceive, are entirely non-combustible, and there will be no cost of maintenance, painting, or any annual expense to them whatever.

Fig. 9*b*—In this, the Monier plates consist of square tile-like pieces put up in hexagonal shape, the corner pieces being arranged so as to assemble and connect the side pieces. This elevator has been built ever since 1892, and its designer, the promoter of the system in Roumania, writes that the construction is considered satisfactory, both from an engineering and a commercial standpoint.

Fig. 10—You notice in this case they carry a few hemlock strips on top of the lower flanges of the girders, with cleats secured to them, and a yellow pine ceiling nailed on from underneath to protect the iron against the fumes of the locomotives. The common construction of buckle plates is shown above. In place of that we submitted a design showing Monier plates instead of buckle plates. The carrying rods are continuous and located near the top of the plates at supports and near the underside of plates between the bearings. Then Monier plates were placed on the lower flanges carrying protecting plates under the girders. The difference in cost is about 50 per cent in favor of the Monier construction.

Fig. 18—It goes without saying that the shape or form of the parabola can be varied at pleasure. You can have it flat or high and, of course, the bottom can be made to suit the wishes of the engineer in charge. You notice the tension rods are so distributed as to take the resultant of the strain, and in the center, where the reaction from the ground occurs, they are placed on top. That is the regular Monier theory.

Fig. 19—Shows the wooden form on which the Monier pipes are usually made, so arranged that it can be taken apart and used again for all the sections. The support for the Monier pipe in a culvert is called a sleeve and is also included in the price per foot for the pipe. The factory furnishes only the wire netting contained in the sleeve, on which common cement mortar is plastered with a trowel, peculiarly shaped to give

the form of the sleeve. This form assures the elasticity of the culvert under high embankments. You will notice that the cost and the weight of Monier pipes as compared with the cast iron pipes is about 50 per cent of the latter, both as to the weight and the cost.

Mr. Heidenreich—I think the remarks made by Mr. Parkhurst are worthy of serious consideration, and I do not feel equal to answering them fully, verbally, tonight, and prefer to do so in writing later on, if you will permit me. There are a number of statements made that are somewhat at variance with my experience and with the experience of those who have helped me to gain whatever knowledge I have of Monier construction. I would also take pleasure in referring to the criticism of Mr. Modjeski later on.

Mr. T. W. Snow—I would like to ask Mr. Heidenreich if it is customary in building those various tanks to use a form on both sides, and if that form, so-called, applies?

Mr. Heidenreich—No; not at all. As shown by Fig. 1, very often they use a mould on the inside or outside of the tank and plaster against it. Of course, this would be quite a cheap method of proceeding, but for tanks going up 100 feet or, for instance, 126 feet in height, the same as in Minneapolis, it goes without saying that it would be far cheaper to use a moving scaffold with moulds on both sides.

Mr. Andrews Allen—I have been much interested in the statements made by Mr. Heidenreich in regard to the elasticity of Monier construction. I would like to have some further explanation of the elasticity of that construction and the reasons for it. I have always understood that concrete would crack if bent to any extent, but presume that the extreme thinness of the Monier plate tends to allow it a certain amount of deflection.

Mr. Heidenreich—I can only refer to the example cited tonight, where a 32-foot span arch with a 3.28 spring was loaded with 2,110 pounds per square foot for half of the arch, and it deflected 11 inches in the center when it was only 7.87 inches thick at the crown. It is a fact, furthermore, that the arch we tried down at Eighteenth and Canal streets, a few days ago, had a deflection of 3 inches in the center—it was only 1¾ inches thick—without as much as a hair crack in it. It is remarkable, but it is so.

Mr. Allen—Did it come back into its original form?

Mr. Heidenreich—No; we broke the arch clear through.

Mr. Allen—I know; but the former example that you cited, did that come back into the original form when the load was taken away?

Mr. Heidenreich—No; it came back within 35 per cent. At least one-third of the deflection was permanent. In quite a large number of cases the Monier pipes have been tested for vertical

pressure (large pipes nearly six feet in diameter), where they have been tested until the limit of elasticity was passed. It was found that the elongation of the horizontal diameter was practically equal to the reduction in the vertical diameter during compression, and when the load was removed less than 35 per cent of the deflection was permanent in both directions. That seems to be a fairly good proof of the elasticity of the Monier pipes.

Mr. Allen—Have there been any experiments to show the amount of deflection which is not permanent; I mean the elastic limit of the Monier construction?

Mr. Heidenreich—Yes; I have records of quite a large number of them, but I do not carry them in my head. Some are contained in the price lists of Monier at Plaine St. Denis, France, of which I have a copy in my office, and if any of the members wish to see it they are welcome; quite a large number of examples of deflection within the elastic limit are shown in table form.

Mr. Allen—Is it a considerable amount?

Mr. Heidenreich—It is quite a considerable amount.

Mr. Allen—Then a considerable proportion of the total deflection is within the elastic limit of construction?

Mr. Heidenreich—Whatever has come under my observation has shown a permanent deflection of less than one-third of the deflection shown during the test.

Mr. J. S. Metcalf—How much of a permanent deflection was there in this arch that you speak of, that had eleven inches of deflection?

Mr. Heidenreich—As I remember it, two-thirds or, say, 65 per cent came back. About 34 and a fraction per cent was permanent.

Mr. C. D. Hill—What was the age of this concrete when it was tested?

Mr. Heidenreich—The arch at Eighteenth and Canal streets, was built April 20 and tested May 30—nearly six weeks.

Mr. Allen—In regard to the construction of sewer pipe as stated in the paper: As I understand it, the carrying rods are placed around the pipe at intervals of some three or four inches. I want to ask if the rods are connected at their ends; whether they are welded and have a connection that will take tension, or are simply interlaced in some way, the concrete bridging the gap?

Mr. Heidenreich—This question has been the subject of quite a number of inventions, patents, etc. There are several methods that have been used. One of them is to run the carrying rods in a sewer pipe in a spiral line continuously around the pipe. This will do for small pipes and small dimensions of wire. Another one is, as particularly patented by Monier, to weld on a hook-like shape on the end of the rod, and wire both ends together. The most modern

method, however, is to bend up the ends of the rods that are to be spliced, let them pass each other twenty times the diameter of the rod, and then wire the two ends together with No. 18-26 annealed wire. The silica connection between the iron and cement is such that it is almost impossible to pull a rod out of cement material composed of one to two and a half, without pulling the rod to pieces, when the diameter of the rod is one-twentieth of the distance in which the rod is immersed in the cement. And, of course, it is true that the strength of the rod at the splice must be equal to that of the rod elsewhere, where it is not spliced. But, it goes without saying, there are a number of different methods of effecting this result.

Mr. J. S. Metcalf—In this Roumanian elevator that you spoke of and illustrated, do you know what the manner of attaching the plates was at the angle—how they were fastened together?

Mr. Heidenreich—Yes. This (sketching on the blackboard) shows the detail section of three sides of the hexagon bins where they connect. Now, the rods are placed in this manner (indicating): The bin sides are three feet high, while the corner pieces are only eighteen inches. After they had been set up properly, an iron rod about ⅝ of an inch diameter was set down in the center space between the corner piece and the slabs, so as to pass through the hoops formed by the protruding carrying rods and a board was placed on each side, and then cement mortar was run in between them, making a firm connection. In that manner, bins were built up fifty-eight feet high.

Mr. Metcalf—How thick were those plates?

Mr. Heidenreich—The plates at the bottom were 5¾ inches.

Mr. Metcalf—And what length?

Mr. Heidenreich—One meter high.

Mr. Metcalf—The length of a span?

Mr. Heidenreich—The sides of the hexagon were about 9 feet from center to center of corners.

Mr. Allen—In the list of different types of concrete steel construction given by Mr. Modjeski, there was no mention of expanded metal. I understand that expanded metal had a very wide use in construction of this very kind. I would like to ask Mr. Heidenreich, or any of the members here, if they can contribute anything in regard to this?

Mr. Heidenreich—All I can contribute concerning expanded metal is what I stated in comparing the New Orleans design for covering the Third street canal with the Monier design. In the New Orleans design they used expanded metal, placing the concrete practically in tension, while the Monier construction placed the concrete in compression and strengthened it by placing the carrying rods in

compression. Of course, for light floors or ceilings there is no doubt that expanded metal would be cheaper than the Monier floor.

Mr. Allen—Is it not entirely practicable to use expanded metal just in the way that a Monier plate is used, and in the arch construction suggested at New Orleans to use a metal base of expanded metal instead of Monier rods? Or, is it not practicable to make a floor plate in the same way, placing the expanded metal close to the top of the plate over the beam and at the bottom of the plate in the center between, and to get the same distribution of steel that you have in the Monier construction, thus placing both constructions on an equality, so far as the structural parts are concerned? In that case I would like to ask if there would be any difference in the cost?

Mr. Heidenreich—I should say that, from the nature of the expanded metal construction, it would be practically impossible to let its structural lines follow the lines of stresses, as laid out by the graphostatically or analytically calculated strain lines through the arches, and, not being able to do so, you could not so place your material to make it effective. Hence, you could not place it to make it economical, and therefore, when strengths are compared, I should say that the Monier construction would be the cheaper. I am not sufficiently familiar with the different ways of applying the expanded metal to attempt in any way to condemn it or criticise it. I know many places where it comes very handy. For instance, for plastering on ceilings, where no loads are expected, and where Monier construction would be entirely too expensive.

Mr. Emil Gerber—I have been very much interested in this paper, and think that there are many places where Monier construction would be applicable. It seems to me, however, that the tendency at present is to run into altogether too light sections. The thin sections which have been shown for arches, tanks, etc., are undoubtedly all right for a short time, but the question arises, how long will they last? Now, while we know that iron thoroughly imbedded in concrete is practicably indestructible, and while the deflection which Mr. Heidenreich has shown to exist in arches without cracking is very remarkable, it seems to me that these structures are subject to accidents which are very likely to crack them; and the thought has occurred to me, is this going to be one of the things (of which we have had so many) for which, when they are first brought out, all sorts of possibilities are conceived and figured out theoretically, but concerning which, after a time, we find, from practical experience, that these extreme possibilities are not realized? In the early days of iron construction, considerably higher stresses were used than now, and probably on material that wasn't anywhere near as good as we get today. When

aluminum first came out it was said to be the softest, most ductile metal on earth, and at the same time the firmest metal to stand compression, and a good many other things that were diametrically opposed. We are now learning that aluminum has many good qualities, and is valuable in many places; but the qualities that were claimed for it at first are not fully realized. Now, it strikes me that the Monier construction in its exceeding thinness is going to be one of those things which after a while we shall make a great deal thicker; and it seems to me the Melan type is an improvement in that line. The Monier rods are very thin. Melan has put in heavier metal, and has used a good deal thicker concrete to protect it.

Mr. Heidenreich—Mr. Thacher, in his paper, said something to the same effect as Mr. Gerber just brought out, comparing the Melan construction with the Monier construction. We must remember, however, that Melan uses a mixture of one to two and a half to five, while Monier uses one to two and a half, making a far more uniform connection between the cement mortar and the steel. Further, we must remember that Monier construction is particularly valuable on account of its extreme simplicity. The simplicity of its parts, being merely round rods, as compared with special shapes which cannot be found in the markets or in the irrigating fields in the west, or in a pinch when you are in a hurry for material, etc., is one of its first advantages, which hardly can be gainsaid. And as for the fact that a new construction, while being advertised, may be over endorsed as to its value in saving material, etc.—that is very true; but we have eight years of experience in France, Germany, Russia, Austria, Norway and Denmark, and the records of these experiments have fully proven the value of the Monier construction today. I have met this kind of objection, that it *looks* too light—have met it every day from laymen and engineers—and now bring the system before you, as professional engineers, so it may be criticised on its merits, and not alone on its looks.

Mr. James McDonald—What is the diameter of those rods in the bins where the different sections are joined together?

Mr. Heidenreich—The vertical rods?

Mr. McDonald—No, the horizontal rods that are placed in the concrete?

Mr. Heidenreich—They varied from the top to the bottom of the bins. They were from three-eighths of an inch to three-sixteenths of an inch in diameter.

Mr. Allen—What unit stresses are used in the rods when calculating the Monier sections?

Mr. Heidenreich—We use from sixteen to twenty thousand pounds per square inch as a safe load.

Mr. Allen—In either the compression or tension ?

Mr. Heidenreich—Either.

Mr. Allen—You figure, then, that the concrete takes all the induced bending in compression sections ?

Mr. Heidenreich—Yes, sir ; absolutely. I will add in this connection, that in exposed steel construction we always use a factor of safety, which some one has called partly a factor of ignorance ; but in Monier construction, where the material — the principal material, the steel or the iron, is entirely shut out from the effects of corrosion, oxidation and electrolysis, and largely from vibrations as well, we do not need the same factor of safety as we do where the steel is exposed to those influences. For that reason, instead of using a lighter strain per square inch, we use from sixteen to twenty thousand pounds.

Mr. Hill—Do I understand that this sixteen to twenty thousand pounds is stress that is allowed for the steel, or for the entire construction ?

Mr. Heidenreich—For the steel alone. We do not, as a rule, consider the concrete either way. We merely consider that as preventing the rod from buckling in compression, and for distributing the tension stresses. For instance, in tanks, helping distribute the strains from rod to rod.

Mr. Allen—Can you cite any illustrations of railroad spans built with these unit stresses ? I want to know how the Monier construction stands impact and sudden loading. Of course, the question of carrying the strains in a tank or a sewer pipe is a different one from carrying strains in a railroad bridge, and the fact that a unit stress of sixteen to twenty thousand pounds is all right for a tank does not establish that it is all right for a railroad bridge. Are these unit stresses carried out in railroad construction, or have there been any experiments to indicate what should be the unit stresses in railroad work ?

Mr. Heidenreich—In reply to this, I will state that, to my knowledge, there is only one railroad bridge built by Monier construction, and that is a very insignificant one — a short span. I think it is between thirty and forty feet. Monier has been used for highway bridges and similar constructions, but, to my knowledge, not for railway bridges, so I cannot speak from experience in this respect.

Mr. E. E. R. Tratman—A point that occurs to me, is in regard to the use of the concrete for tanks. There is often considerable trouble with leakage from concrete, either by fine cracks or by the porosity of the material. If any leakage should occur in either way through the walls of a Monier tank, it seems to me the moisture

would very quickly attack the steel construction. Oil, of course, would not attack the steel, but I should think oil would be difficult to retain, unless a special kind of concrete is used. I should like to know if any cement plastering is applied to the tanks?

Mr. Heidenreich—In reply to that, I would state that for oil tanks there is but one cement, so far as I know, that has proved itself satisfactory, which is the Vinat cement, made in France. A mixture of cement mortar is really not a concrete; it is a mortar, generally one to two and a half. It is plastered on the inside form in layers, and plastered very carefully. As for water tanks, they are plastered from the outside or from the inside, and the concrete or the mortar is so well mixed, and the cement is of such excellent quality, that I have never heard of any Monier water tanks built by the Monier people which have leaked. There is no record of any such occurrence.

XCV.

COLOR PHOTOGRAPHY.

This subject was treated in a charming and instructive manner at a special meeting of the Western Society of Engineers on May 18, by Messrs. Flora and Douglass. These gentlemen gave many beautiful illustrations by means of lantern slides, covering a wide range of subjects. Scenes along the Nile, and again in Norway, as well as in our own beautiful parks, were shown by the lantern. There was also shown what might be called commercial work; that is, the presentation in their correct colors of articles of trade, such as vases, showing the brilliant colors and beautiful enamels of the art products of the potter's craft. Again, there were samples of carpets, wall papers, and the like, showing correctly the colors, individual or in combination, of the design.

Portraiture was also shown, and in the natural colors, that was very satisfactory. The beautiful displays of delicate dress fabrics, which can be seen in all their glory in some of the State street windows, were thrown upon the screen in a realistic manner. But the views of natural scenery were in the majority and very pleasing. The various shades of the green of grass and foliage, the many hues of the flowers, the blue of sky and of water, the brilliancy of sunshine, contrasting with the purple tones of shadows, were all brought out on the screen as in nature. A simple informal introduction was given by Mr. Flora on the composition of light and color. He showed by experiment that, contrary to the earlier teachings of this subject, there were only three primary colors, viz: red, green and blue, and that by a proper combination of these, all other colors and shades can be produced. He said:

Light is the sensation produced by the action of luminous rays upon the retina of the eye. A luminous ray is due to a propagation of a wave motion of the elastic medium called ether, which pervades all space. The physical cause is created by the luminous rays entering the eye and falling upon the terminal expansion of the optic nerve, which forms a lining or membrane at the back of the eye, and is called the retina. These luminous rays stimulate the retina and give rise to a sensory impulse transmitted to the brain by the optic nerve, and is there transformed into a sensation. The luminous rays have different rates of vibration, thereby creating different sensory impulses and different sensations on the brain. The modern theory of what is called color, advanced by Young, Helmholtz, Clerk-Maxwell and others, divided these impulses of the luminiferous ether into three sets, or rather the vibration or waves of light give three different sensations to the brain by their independent action on what is called nerve fibrils. These nerve fibrils are divided into three sets. Certain impulses or waves of light, giving what is called a red sensation, act through one set, and through another set, those that give a green sensation, and those giving a blue sensa-

tion act through still another set. It follows, then, that all color is simply due to different impulses of the ether, acting through one or more sets of fibrils, giving the sensation of red, green and blue, or their mixture in part or whole. When all three nerve fibrils are acted on equally, we have what is called white light, or that sensation is transmitted to the brain. In the absence of these impulses we have no sensation, and all is darkness. These impulses may be retarded or their sensations reduced in many ways. One of these conditions, and it is found in many eyes, is the partial or entire paralysis of one or more sets of these nerve fibrils; the condition when it exists stimulates the remaining sets or parts of sets of the nerve fibrils to action, and gives the sensation of tints different, or colors other than exist in the original subject to the normal eye. This defect is called color blindness. Another method is by viewing the object through colored glass, or under colored light, thereby absorbing or obstructing the impulses from the color subject. If we look through a red glass all the colors except the red impulses are obstructed or absorbed, and we have only the red sensation. A green glass gives the green sensation, and a blue glass the blue sensation. This follows the laws of the mixture of colored light, and not of pigments. The mixture of colored lights is the juxtaposing of colors or their sensation when viewed side by side. The mixture of pigments is the superposing of different colors or their effect by combining them in close contact, such as painters use in mixing colors in oil or white lead. The McDonough process follows the first law; that of the mixture of colored light. Three colors are selected from the spectrum; the first an orange red, the second a yellow green, and the third a blue violet. These colors, when placed on a disc which is equally divided into three sectors, representing the above named colors, and when the disc is rotated rapidly, give practically the sensation of white light, depending on the purity and transparency of the colors used. When these three colors are ruled in very fine lines, as in the McDonough method, being from three to five hundred to the inch, the resultant sensation of white is the same as in the rotating disc. The linear areas being too fine for the eye to separate, their combination gives the sensation of white light. When one or more of these areas are covered by black lines in part or whole, then the resultant sensation is the mixture of the remaining areas which are left uncovered by the black lines. In making a negative by the McDonough process, a "taking screen," or glass plate lined or ruled in the three fundamental colors, such as orange red, a yellow green, and a blue violet, is placed in contact with the "Erythro" dry plate. The exposure is then made, the light from the object photographed passing through a "chromatic balance shutter," or filter, which is adjusted on the hood of the lens, and, after exposure, the plate is developed in the usual way. This negative, when viewed closely, shows fine linear areas of different degrees of density. These areas represent the different values of the color of the object photographed, as the light from it passes through the lined "taking screen" in the camera. This "taking screen," lined in the three colors, absorbs or transmits the colors from the object just in proportion as it requires a mixture of part or all of these three colors to produce the colors in the original subject. For example, if we have a yellow subject, and there being no yellow line in the "taking screen," it follows that, as yellow is the mixture of red and green light, it will act through the red and green lines of the "taking screen" just in proportion as the yellow in the original subject is an orange or greenish yellow, and its value is found upon the negative in two lines of varying density representing the red and green lines; while the blue line is left transparent, from the fact that the blue line in the "taking screen" absorbs the yellow light from the object photographed. All colors are mixtures in part or whole, of the three colors ruled on the "taking screen." From the negative with the color value lines as described, we make a glass transparency or positive by superposition, and in contact with the transparency or positive so obtained we place a "viewing screen," which in number and color of the lines is a duplicate of the "taking screen." Then bring the linear areas of the positive and viewing screen into parallel or register, so that the red values of the positive fall over the red lines of the viewing screen, the green values over the green lines, and the blue values over the blue lines. This being done, we have an exact representation or reproduction in color of the original subject photographed, when viewed by transmitted light, as in a transparency or lantern slide.

Photographs in color on *paper* by the McDonough method are made from the same negative on sensitized chromatic paper, printed in sunlight; then toned and

fixed as in the usual photographic process. The perfect register of color value lines on the negative and the lines in color on the sensitized chromatic paper is secured by a special printing frame made with adjusting screws.

For illustrations in magazines, books, catalogues, etc., the same negative that makes the glass positive and prints on the sensitized chromatic paper is used to make a copper half-tone plate, or block, and on a press specially made for the work, the copper half-tone block prints in black ink on the three colored lines that are first printed upon the paper by separate cylinders.

The chromatic balance shutter, which is a necessary adjunct to the camera for taking negatives for color work, is a "light filter," consisting apparently of a thin transparent disc stained yellow and held in a metallic frame by which it can be attached to the front end of the lens tube of the camera. As a matter of fact, this screen is made up of two sets of circular sectors of thin glass or mica, one set colored a greenish yellow and the other set an orange yellow. The relative areas of these two sets of sectors can be changed at will by the movement of a little index bar on the outer edge of the frame. The object of this is to filter the light entering the lens through a greater or less proportion of the orange yellow colored sectors, depending upon the condition of the light, whether it has an excess or otherwise of the blue rays of light. The sensitive dry plate to receive the impression of the rays of light from the object to be photographed, must be one specially prepared to be sensitive to the colored rays of light; that is, one in which the haloid salts of silver are in such proportions and combinations that the plate is more sensitive to the effect of the yellow rays of light than the ordinary dry plate. These plates are called by the makers the "Erythro" plate, and are necessary to secure good negatives for color work.

A most important adjunct to the camera is the "taking screen," which is a thin plate of glass coated with a colorless gelatine film, and afterward ruled with fine parallel lines at the rate of 300 to 600 per inch. These lines are of colored ink, an "orange red," a "yellow green," and a "blue violet," and in the order named, with the lines in juxtaposition. But so fine and narrow are these lines that, to ordinary eyesight, the plate appears to be of a grayish or neutral tint. If examined under a magnifying glass the color definition and juxtaposition of the lines can be clearly seen. This taking screen must be brought into contact with the sensitive Erythro plate, that is in the holder in the camera, before the exposure is made. As the several rays of light from the object to be photographed, having their respective colors—red, blue, green, yellow, or whatever it may be—pass through the taking screen the colors are filtered by these colored lines of the taking screen, and the proper color that gets through the colored lines of the taking screen affects the haloid silver salts in the sensitive plate, so producing a

greater or lesser density in the plate. But color does not show in the developed negative, only a greater or lesser density in the film on the plate, in narrow parallel lines, which correspond to the lines of the taking screen. The color can be had from this negative by preparing a "positive" from it, and then viewing the positive through the medium of a "viewing screen" of the same ruling and color as the taking screen, and which must be superposed on the positive plate. When this is done, the viewing screen being carefully adjusted in position on the positive plate, so the respective color lines of the viewing plate are in "register" with the corresponding lines of the positive, then, if viewed by transmitted light, whether as a transparency or a lantern slide, the picture will be seen with the proper colors of the original object.

"Process plates" and pictures can also be made by this method. First, the paper to receive the process print is prepared by means of a platen press in three separate steps or impressions, so that the paper will show fine parallel lines of the same three colors — red, green and blue — and of the same color, order and magnitude corresponding to the viewing or taking screen. This printed paper, when looked at without magnification, shows the same appearance as the screens — a grayish or neutral tint — but under a magnifying glass there can be seen the fine, yet distinct, colored lines of the viewing screen. The fourth impression to produce the finished picture is from a copper half-tone block prepared from the selected negative, consisting of narrow parallel lines of greater or less intensity, which correspond in direction and spacing to the original taking screen, or as in the negative; but with this difference, that in the original negative there were transparent lines corresponding to the absence of color in the original subject, while in the copper half-tone plate there are full lines to take the ink. When this process copper plate is placed in the printing press, and with the register carefully adjusted, the black ink blots out those colored lines originally printed on the paper, which are not needed, and the colored lines that are not blocked out by the black ink show the color that is in the original subject, and thus gives a picture with the correct colors, and so disposed as to give the proper effect in the picture.

But this manner of making a colored half-tone print is now somewhat slow, necessitating four impressions through the press from the white paper to the finished picture. A new and improved press is being built for this color work by which it is expected to print the three colors and the final half-tone print in black, in one operation, and in one handling of the paper through the press.

The machinery for ruling the taking and viewing screens is of beautiful construction and capable of the nicest adjustment, but is

too complicated to describe in this article. An idea may be given, however, when it is known that these ruling machines must be kept at a uniform temperature and inside of glass cases to keep all dust from the ink or plates. The ruling device is a disc with a V-shaped edge, about 1½ inches in diameter, and made of agate or hardened steel. The steel discs can be brought to a fine edge, and are uniform in their texture, but are liable to corrosion from the ink, and require a good deal of care to keep them in order. The agate ruling discs are not affected by the ink, but are more liable to fracture or to lose a portion of the finished edge by spalling. These discs are mounted on hardened steel arbors running in hardened steel boxes, and any grinding or polishing of the ruling edge is done with the disc revolving on its own arbor. The frames with the boxes carrying these discs are so arranged (they can be adjusted with the greatest exactness) that the lines of colored ink that are ruled on the screens are of the proper width and in juxtaposition.

The credit for the discovery of this method of color photography belongs to Mr. James W. McDonough, who gave twenty years of his life in perfecting his process. Mr. McDonough died in July, 1897, but the work has been carried on since by Mr. Flora, who had been his laboratory assistant. W.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

PARK ROADS.

[*Abstract of a paper by Mr. J. F. Foster, superintendent of the South Parks, Chicago, presented to the American Park and Outdoor Art Association, Chicago meeting, June 7, 1900.*]

Park roads are regrettable necessities, though the necessity of a road is frequently overestimated.

The landscape architect should note the broad distinction between parks and cemeteries, in each of which he is called upon to exercise his engineering knowledge and artistic skill. The cemetery, by the very needs of its creation, demands the cutting up of the land into comparatively small lots which must be readily accessible by wheeled vehicles; but, with a park, of the first importance is the expanse of sward, with the grouping of shrubbery, and the planting or conserving of trees. Hence, as a general rule, roadways should be kept in as subdued and minor character as possible. The allowable exception to this is for a few broad carriageways to meet the demand of the driving public; and this feature belongs more to boulevards than to the park proper. To serve the highest purpose of the park it should adhere as closely as practicable to the work of nature, and all artificial adjuncts should be made as unnoticeable as possible. For people to get the best influences from the park they should walk over the grass, under the trees, and through the coppice, and be as near to nature as possible.

The crown of artistic success is placed upon any design, whether for a park or a building, when the simple fitness for the uses to which it is to be put is beautifully apparent; and hence, in a park the more grass, trees and shrubbery the better. Roads should be introduced only as necessity demands. Every unnecessary square yard of roadway detracts that much from the essence of the park — the restfulness of grass and trees.

But park roads being a deplorable necessity, the question of how best to plan and construct them is the important one. Boulevards are necessarily formal and artificial creations, and it is right that they should be direct and straight, as a rule, with precise and regular rows of trees. In the park, on the contrary, the roads, with few exceptions, should not be wide and, if irregularly winding and among the trees, if more completely hidden from sight, so much the better.

Their construction largely depends upon local conditions. The

character of the natural earth upon which is built a roadway largely controls the method of construction. A naturally drained subsoil presents little difficulties to road building; but an impervious clay soil requires special treatment. In the clay ground, if the subsurface of the roadway is so arranged that the water, which will percolate through the ballast, can drain off freely, much subsequent expense and annoyance will be avoided. To underdrain a clay soil with tiles or otherwise, where a road is to be constructed, gives the best results; but this is an expense which generally is not essential. What needs to be guarded against is the action of water and frost in breaking up the "bond" of the roadway material. If this happens with water held within the ballast, every passing vehicle will cut up and rut the surface and necessitate expensive repairs thereafter.

The thickness of the roadway material depends upon the traffic; but, in general terms, for a traveled boulevard or driveway the thickness need not exceed 12 inches, if properly cared for, and for most park roads, where there is less driving, 9 inches will be found sufficient. At some minor places, with little travel, such as temporary turnouts and hitching places, the thickness may be as light as 5 inches, if on good sand, but not less than 7 inches on clay. The thicknesses above given for the general roadways are not so necessary to hold up the traffic as to provide for the wear of the surface, and thus avoid too frequent resurfacing. The surface of such roadways may be worn down 2 or 3 inches before it is resurfaced.

As an example of a boulevard roadway, and of the wear upon the surface, is Michigan avenue, where frequently there are 13,000 vehicles passing over the road in 24 hours. The wear here is considerable, and the surface may be worn down 3 inches within a couple of years. It should then be resurfaced. If the winter should be a wet one, with reduced thickness of the material to say 6 or 8 inches, there is risk of teams cutting through and destroying the roadway. Hence the necessity of keeping up the thickness by using sufficient material in the original construction, or by more frequent resurfacing.

As to the material to be employed, it is generally conceded that there is nothing better than good, sound, crushed stone, capable of withstanding the disintegrating effect of frost. The surface, or wearing part, should be tough and hard, but the bottom portion, of 6 to 9 inches thick, may be a softer stone if not affected by wet and frost.

The surface stone, preferably of a tough and hard granite or trap rock, should be broken into cubical fragments to pass through a 1¼-inch ring in the largest dimensions, but the bottom stone,

which in this locality can be of limestone, should be larger, to pass through a 2½-inch ring.

Though granite or trap rock is advocated for the surfacing and is, I might say, imperative for the boulevards and main drives, yet on the outer boulevards and the less used park roads a cheaper material may be substituted. Consideration should be given to the color of the surfacing material. The white glare from limestone macadam is very unpleasant to the eyes, and the contrast with the adjacent grass and foliage is too great. A darker color should be used. Some bank gravels have a reddish or yellowish color, which is acceptable as far as color goes, and as found they generally make an excellent surface, where travel is not too heavy, except that they are apt to be muddy in wet weather, or dusty in dry weather if not constantly sprinkled.

If the cost of the top 3 inches of surfacing material, if of a dark granite or trap is too great, a thin surface layer of fine crushed granite can be used, but a thin layer needs renewing that much more often. The thicknesses mentioned are of the roadway after a thorough consolidation by rolling.

For the form of the road, the crown should be, as nearly as may be, 2 per cent of its entire width, and the center line should be on a regular grade, and not rise and fall with the gutters as is sometimes the case. The grade at the gutters should fall not less than 1 in 300; and ½ of 1 per cent is a better grade. Gutter grades of less than 2 per cent do not require to be of harder material than macadam. The most satisfactory gutter, as to maintenance, is of paving brick, though where there is no curb, as should be the case in park roads, a flat cobble-stone gutter is more pleasing in appearance.

Catch basins for the drains should be not to exceed 200 feet apart, but in narrow drives, or in broad drives on sharp grades, the intervals should be shorter.

The proper width of a park road depends upon the point of view of the park designer. If the road is to be a fine carriage promenade or boulevard, the users of which are to receive every attention, then he will wish to lay out a roadway of 50 to 60 feet wide, or more. But if the designer has due consideration for the far greater number of people who do not drive, and if he wishes to subordinate the roadways to the park proper, a width of 35 feet will be found ample, as a general rule.

The maintenance of the road is a simple matter, and that is, simply, to maintain it. Maintenance should begin the day the road is completed, and not wait until the road needs actual repair. After that it is only a case of repairs, and always unsatisfactory until the road is resurfaced. Of the first importance in the main-

tenance of a road is proper sprinkling. Observe this rule: Always make the road damp enough to prevent dust, but never wet enough to make mud. This is of importance to the preservation of the road, as well as to the comfort of the users. The proper, sufficient, and not excessive sprinkling, is a difficult thing to obtain. The drivers of the sprinklers should be above the average in intelligence; should have experience, and be willing to do whatever work was necessary to secure the desired results. Have the sprinkler cart properly built, and the sprinkling device fully under the control of the driver, so the quantity of water used can be regulated. Beyond all this, is the necessity of eternal vigilance on the part of the person responsible for this work.

The cleaning of the roads is almost of equal importance with the preceding. The regular use of a sweeper is probably best, if handled in such a way as not to disturb the integrity of the roadway material.

Patching a road is necessary, and can be done with limestone, gravel, or some other moderately soft rock. But patching, or filling up of depressions, will not preserve a road. In time, it will have to be resurfaced. This comes when the surface has been worn down about 3 inches. It should be well understood that this resurfacing is simply loosening up the old surface, adding the necessary new material and then sprinkling and rolling until thoroughly compact. In this connection, it will be found of great advantage to run the roller over all roads in the spring, after the frost is out of the ground, to compact the material and put the surfaces in good order. This is the time, also, to add a little fresh surface material, here and there, as may be needed to fill up slight depressions. The result for the following season fully justifies the cost.

The preceding remarks apply to macadam or gravel roads. Hard roads, to be made out of brick, stone, asphalt, etc., have no place in a park, if any pleasure is to be had in driving; that is, if one has any regard for his horse. When the automobile entirely succeeds the horse, then such a hard, smooth, monolithic surface will be in place, and will be demanded, but that is not yet. The park road to be satisfactory must possess three qualifications, viz: to be in good repair, clean and properly sprinkled. These conditions can only be had by constant attention, good management and the expenditure of money.

Parks may be considered luxuries, but, if a luxury, the more necessity, then, that it be near perfection of its kind—and this means excellent maintenance. There is no place in a park that shows lack of maintenance so pointedly as does the road. Do not let the beautiful and luxuriant vegetation of the park be marred by

an ugly, unkempt road. Again, do not multiply your roads to increase the sum total of cost of maintenance, but let the park be a piece of the country, with roads only to reach its beauties, and these through woods, planted on both sides, hidden. Let the roads in the parks be the quiet, peaceful ways for the lovers of nature.

W.

THE PRESERVATION OF RAILROAD CROSS TIES.

[*Abstract from Proceedings of the Eastern Maintenance of Way Association.*]

The report at the Portland, Me., meeting, September, 1899, of the Eastern Maintenance of Way Association, prepared by Mr. F. R. Coates, of the N. Y., N. H. & H. R. R., Mr. C. B. Lintell, of the B. & A. R. R., and Mr. C. S. Osgood, of the O. C. R. R., was on the question as to whether it is good economy on the part of the New England railroads to treat all cross-ties chemically.

The answer to this question would depend upon the process employed for chemical treatment.

There is no question but that the decay of wood in exposed situations can be greatly delayed by certain chemical processes. There have been many processes invented and tried, but the result at the present time is that there are only three processes which possess commercial worth. These are "kyanizing," using chloride of mercury or corrosive sublimate; "creosoting," using "dead oil" or "pitch oil" from coal tar, and "burnetizing," using chloride of zinc.

The first of these, kyanizing, is objectionable because of its cost and the very poisonous and dangerous nature of the chloride of mercury, and which is also so soluble in water as to be easily washed out of the pores of the wood by the action of heavy rains.

The second, creosoting, is excellent, if great care be exercised to get a good and reliable article of "dead oil" (which is very liable to be adulterated), and also if the treatment of the wood be judicious. The temperature of the wood in the impregnating cylinders must not be too high. Open grain and porous woods seem most benefited by this treatment. When well done, with proper material, there is no question as to its preservative action on the wood. But to get good results, expensive and expert superintendence is necessary, as well as a costly plant, which must generally be located at some one point. All material, railroad ties, etc., has to be brought to this place, and after treatment the timber or ties have to be hauled away again to where wanted. Hence, there are but few parts of the country where the price of ties is such that the expense of treatment of them, by this process, is not almost, if not quite, prohibitory.

The third process, using the chloride of zinc, is objectionable from the action of this powerful antiseptic on the timber. If used in sufficient quantities to preserve the wood from decay, then it makes the wood very brittle, and destroys its elasticity and strength. The opinion is expressed that it would not at all do to have timber, which might be subjected to heavy cross strains, "burnetized" or treated with the zinc chloride preservative. When railroad cross-

ties have had this treatment, the trackmen must exercise great care to keep the ties thoroughly tamped up under the rails.

If the zinc chloride solution is used sufficiently diluted as not to injure the wood fiber, the chemical is so soluble it is readily washed out of the pores of the wood by the action of rains, and then decay quickly follows. Various attempts have been made to prevent this escape from the wood, of the zinc chloride, by some method of "plugging up" the pores of the wood, but they have not proved successful.

It was not until some 30 years after the discovery and application of the creosote process, and of the burnetizing or zinc chloride process, that a combination of the two was made; and it was still later before the value of this combination was recognized.

The efficiency of chlorine compounds as antiseptics is unquestioned, and the great durability of certain coal tar products, containing creosote, is well known. Now, the point is to make such a compound of these as will be readily absorbed by the wood without the necessity of a costly fixed plant for the treatment of the timber, but which can be applied by ordinary unskilled labor in any locality wherever the timber may be.

The comparatively low price of railroad ties in this country has too long made us indifferent to their economical use, and to the great value of prolonging the life and usefulness of the wood by the application of some preservative treatment.

The conditions are different in Europe; there the cost and value of timber is much greater than here, and the railroad managers have been forced to investigate and experiment most fully and carefully along these lines. The result of these experiments have led to the more general use of a compound of zinc chloride and creosote oil. This compound, called carbolinium avenarius, has been very fully described by Mr. C. A. McKinny in a paper presented to the Engineering Association of the South in April, 1897. He states that this preservative can be applied to the wood by dipping, or by brushes, as though it was a paint. It seems to be readily absorbed by the wood, and the expense of tanks, vacuum and pressure pumps, and all that goes to make up a wood preserving plant, is not necessary.

One peculiarity of wood treated by this compound that was noted by Dr. J. Edward Lingard, of Derby, England, is, that wood so treated not only loses weight, by the drying out of the water in the wood, but also does not so readily absorb water when exposed to the wet. This was shown by Dr. Lingard, who took sample pieces from the same railroad tie and had half of them treated by this compound, and afterward all were alike exposed to the weather,

including a heavy rain storm. The treated specimens did not absorb the moisture as the untreated pieces did.

The value of this compound having been demonstrated, and its ease of application considered (not requiring any extensive plant to which the railroad ties must be taken for treatment), then the answer as to the value of so treating railroad ties is in the affirmative. It would be a measure of economy on the part of the New England railroad companies to treat all cross-ties chemically with this chlorine-creosote compound.

The points in its favor are:

First. It is a finished definite chemical compound. Each lot, if desired, can be analyzed at small expense, and its nature and standard chemical value determined, and the imposition of worthless material prevented.

Second. It is self-impregnating, and, owing to its high specific gravity and peculiarly penetrating properties, no machinery is necessary to force it into the wood, but into the pores of which it readily enters upon mere application, especially when the compound is applied hot, as is advised when the wood is not thoroughly seasoned or the weather is cold. It can, therefore, be cheaply and economically applied to wood anywhere by unskilled workmen.

Third. Close grained woods, such as chestnut, white cedar and tamarack, which cannot be so well treated by the old creosote or zinc chloride processes, can be successfully treated by this combination process, which also gives fully as good results in the treatment of the softer and more open grained woods, and at an expense of less than one-half the cost of the old methods.

Fourth. The powerful antiseptic properties of chloride of zinc are, in this combination, fully secured and rendered lasting by the indestructible nature of the creosote compounds with which it is associated, and, at the same time, the properties of the zinc chloride destructive to wood fiber and weakening to its strength when applied in aqueous solution, are completely antidoted by the oleaginous constituents of the coal tar oils, so that the life and vitality, the spring and toughness of the natural wood is fully retained, instead of being sacrificed to thermal action or chemical action as in the old processes.

The cost of treating cross-ties varies somewhat with the wood used, as the softer, open grained woods absorb more of the compound than a denser or harder wood. To assume 15 cents for the cost of treating an average cross-tie is a very liberal allowance, and the life of the tie is increased from 6 years for an untreated tie to 18 years or more for treated ties. Assuming the cost of the tie originally to be 50 cents, and the hauling to destination to be 6 cents, and the placing in the track to be 10 cents, then the cost of the untreated tie in the track would be 66 cents, and the treated tie would cost in the track 81 cents.

Assuming the life of the untreated tie to be 6 years, and that of the treated tie to be 18 years, and allowing a 4 per cent interest charge, the cost per year for the untreated tie is 13.64 cents against 7.74 cents for the treated tie. This is a saving of nearly 6 cents (5.9 cents) per tie per year, or nearly 12 per cent on the original cost of the tie. In addition to this profit, or saving, by the use of treated ties, should be added the saving in the labor account in

making two renewals in this 18 years, including the labor of resurfacing the track, which had been disturbed. Taking all these points into consideration, the committee were unanimously of the opinion that it would be a measure of economy for the New England railroad companies to treat all their cross-ties by this chlorine-creosote process. W.

PRESERVATION OF TIMBER FROM DECAY.

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[The following partial list of articles published by various societies and writers on the subject of the "Preservation of Timber from Decay," is commended to the attention of such of our readers who have an interest in this matter. The list is not arranged by authors, nor in chronological order. Though not complete, it is believed to cover the ground fairly well.– THE PUBLICATION COMMITTEE.]

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Vol. XI, p. 325 et seq.

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ABSTRACT OF MINUTES OF THE SOCIETY.

SPECIAL MEETING, APRIL 18, 1900.

A special meeting (the 421st) of the Society was held in its hall on Wednesday evening, April 18, 1900. President Ambrose V. Powell in the Chair. Business not being in order, the reading of papers was taken up. In the absence of the author, Mr. Chas. H. Davis, of New York city, of a written discussion on the paper, "Are Present Methods of Train Protection Adequate?" the Secretary read the discussion, which was illustrated by lantern slides. A brief discussion followed the reading.

Mr. B. C. Rowell then presented a number of lantern slides illustrating the signal device referred to in his discussion of this subject March 7, 1900, which was printed in the April issue of the JOURNAL.

The chair called for discussion on the paper; "What Does it Cost to Run Trains at High Speed?" prepared by Mr. F. A. Delano, copies of which had been sent to members, but none was forthcoming.

Before adjournment, the chair announced the death of one of the esteemed and prominent members of the Society, Mr. Dankmar Adler. Mr. F. H. Bainbridge made a motion that the chair be authorized to appoint a committee to draft suitable resolutions on the death of Mr. Adler.

The motion was seconded and carried.

The meeting adjourned.

REGULAR MEETING, MAY 2, 1900.

The regular meeting (the 422nd) of the Society was held in its hall on Wednesday evening, May 2, 1900. President Ambrose V. Powell in the Chair, and 45 members and guests present. The Secretary read the minutes of the previous meeting, which were approved.

The report of the Board of Direction was read, announcing the election on the 2nd instant of the following as active members: Frederick T. Barcroft, Adolph Sorge, Jr. As junior members: Henry Dakin and Clinton McDonald. The committee on memberships returned letters of resignation received from E. J. Ward, S. L. Heidenreich, C. J. Roney, H. C. Powel, Wm. Powrie, H. L. Hollis, R. S. Walsh, Geo. E. Dixon, F. W. Settan and C. H. Mercer, and recommended acceptance of the resignations. A motion was made to that effect, seconded and carried. The following applications for active membership were received and referred to the membership committee: John C. Dorst, Wm. H. Elliott and Benton C. Rowell.

The paper for the evening, "Parks and Boulevards," was read by the author, Mr. A. C. Schrader. This paper is given in another part of this issue.

The discussion which followed, related to the question of economy in the use of macadam as against block and asphalt; and the using of crushed granite rather than crushed limestone in cities for base for sidewalk, on account of its greater durability. Limestone is used where the sub-drainage is not satisfactory, for the reason that it absorbs a great deal more water than does the granite and secures a firmer binding with the concrete.

Mr. Schrader stated that good cinders were very generally used for sub-base, and the concrete laid directly on the cinders, the cinders preventing the heaving of the sidewalk, especially on a clay subsoil. Further discussion on maintenance and the cause of failure in the gutter was had.

Those taking part in the discussion were: S. G. Artingstall, the Chair, A. C. Schrader, A. C. Warren, B. E. Grant and G. P. Nichols.

The meeting adjourned.

SPECIAL MEETING, MAY 16, 1900.

A special meeting (the 423d) of the Society was held in its hall on Wednesday evening, May 16, 1900. Vice President W. H. Finley in the Chair, and 51 members

and guests present. The meeting having been called for the reading of papers only, no business was transacted.

The first paper of the evening was, "The New Building for the College of Engineering of the University of Wisconsin," prepared and read by Prof. J. B. Johnson, dean of the College of Engineering, at Madison, Wisconsin. The paper was full of interest, as the extended discussion verified.

The full text of the paper appears in another part of this issue of the JOURNAL. The discussion took up the manner of hanging the partitions, and the lathing used, and a great deal of attention was devoted to the subject of artificial lighting. The heating and ventilating questions were discussed at considerable length. Those taking part in the discussion were: F. L. Hill, Prof. Johnson, J. H. Warder, T. L. Condron, Director G. N. Carman of Lewis Institute, O. C. Simonds, B. B. Carter, Prof. C. V. Kerr, of Armoui Institute, and others.

The further discussion of Mr. O. Chanute's paper on "Preservative Treatment of Timber," was next taken up. A written discussion, prepared by S. M. Rowe, was read by the Secretary in the absence of Mr. Rowe.

In the discussion which followed, Mr. Onward Bates endorsed the treatment of timber on economic grounds. In answer to the question whether the treated tie holds the spike better than the untreated, Mr. Chanute stated that after the treated tie has had time to dry, it holds the spike much better than the untreated tie. Further discussion on other features was had by the Chair, Mr. Bates, S. G. Artingstall, H. P. Boardman, Mr. Chanute, Prof. Johnson and D. W. Maher.

The meeting adjourned.

SPECIAL MEETING, MAY 18, 1900.

A special meeting (the 424th) of the Society, to which ladies were invited, was held in its hall Friday evening, May 18, 1900. Mr. Ralph Modjeski in the Chair, and 35 members and guests present. The weather was stormy and disagreeable.

The meeting was called for entertainment as well as instructive interest, to witness an exhibition of the results that have been attained in photographing colors and a demonstration of the principles used in the process. This exhibition was given by Messrs. E. E. Flora and G. A. Douglass. Mr. Flora was introduced, and explained the principles of the process and was followed by Mr. Douglass, who explained some 200 lantern slide pictures of flowers, landscapes and many beautiful scenes, as they were thrown on the screen in the rich colors seen in their original state.

The entertainment was delightful aud thoroughly enjoyed by those who had the courage to brave the elements. A vote of thanks was heartily tendered Messrs. Flora and Douglass.

The meeting adjourned.

REGULAR MEETING, June 6, 1900.

A regular meeting (the 425th) of the Society was held in its hall at 8 o'clock Wednesday evening, June 6, 1900. President Ambrose V. Powell in the Chair and 35 members and guests present.

The minutes of the last meeting were read by the Secretary and approved.

The report for the Board of Direction showed the election to active membership of John C. Dorst and R. H. Moth, and Emil K. May was transferred from junior to the grade of active member.

The resignations of W. O. Seymour, H. G. Hetzler and H. J. Westover were received and accepted.

There being no other regular reports, the Chair announced the appointment of Mr. E. C. Shankland, chairman, and Messrs. C. E. Billin and B. J. Arnold as a committee to prepare suitable memorial on the late Dankmar Adler.

Also, James J. Reynolds, chairman, and Messrs. Isham Randolph and Robt. W. Hunt as an entertainment committee.

Mr. Samuel G. Artingstall arose and stated that some months ago he was appointed chairman of a committee to secure subscriptions for the 34th National Encampment of the Grand Army of the Republic, which is to be held in Chicago, beginning on the 27th of August, 1900, and that he had been promised ten dollars from some parties, and suggested that the collections be made by the committee as soon as possible.

The Chair then presented Mr. E. L. Heidenreich, who read his paper on "Monier

Constructions." The paper was freely illustrated with lantern slides. At the conclusion of the paper, the Chair called upon Mr. Ralph Modjeski who read a written discussion.

Mr. H. W. Parkhurst had prepared a written discussion, but not being present the Secretary read it. These two discussions made brief criticisms of the Monier system and referred to the principal features of other systems.

The Chair then announced the meeting open for a general discussion. Mr. Heidenreich made a brief statement in reply to the criticisms. The oral discussion brought out a variety of interesting questions to which Mr. Heidenreich made answer. Among those who added interest and information by active participation were Messrs. S. G. Artingstall, T. W. Snow, Andrews Allen, J. S. Metcalf, C. D. Hill, the Chair, Emil Gerber, James McDonald and E. E. R. Tratman.

The attendance of guests was unusually large, evincing the interest the subject aroused.

The paper and discussions appear in another part of this issue of the JOURNAL.

The meeting adjourned.

NELSON L. LITTEN, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL we have received the following gifts from the donors named:

R. R. Commissioners, State of N. Y., 17th Annual Report, Vols. I and II.
Mr. Albert McCalla, Practical Mechanic & Engineer's Magazine, Vols. I to VI.
Transactions Institution of Civil Engrs., Vols. I and II.
Chas. S. Palmer, Outlines of the Theoretical Chemistry of Copper.
L. G. Carpenter, 12th Annual Report, Agricultural Experiment Station, Colorado.
School of Practical Science, Toronto, Papers read before the Engineering Society.
U. S. Geological Survey, 19th Annual Report, 1897-8, P. 2, 3, 5 & 5, Atlas.
20th Annual Report, 1898-9, P. 1, 6 & 6 cont.
Monographs XXXII P. 2, XXXIII, XXXIV, XXXVI, XXXVII, XXXVIII.
Bulletins, 157 to 162.
U. S. Treasury, Annual Reports 1899, Commerce & Navigation of U. S., Vol. I.
Institution of Electrical Engineers, Journal issued April, 1900.
University of Illinois, Catalogue 1899-1900.
Purdue University, Catalogue 1899-1900.
D. H. Ainsworth, Recollections of a Civil Engineer.
B. F. Sturtevant Co., Mechanical Ventilation & Heating by a Forced Circulation of Warm Air, by Walter B. Snow.
The Application of Mechanical Draft to Stationary Boilers, by Walter B. Snow.
L. L. Buck, Commission New East River Bridge, Specifications, etc.
War Department, Examination and Survey of Alexandria Harbor, La.
Feasibility and Propriety of Filtering the Water Supply of Washington, D. C.
16th Report of the U. S. Civil Service Com.
Secretary of War, Official Army Register for 1900.
Wm. S. Hancock, Comptroller, Annual Statements of Railroad & Canal Companies of State of New Jersey, 1899.
R. R. Commissioners, Massachusetts, 31st Annual Report, January, 1900.
Montana Society of Engineers, Constitution, By-Laws, Officers and Members.
Ralph Modjeski, Commercial Directory of the American Republics.
J. R. Mann, Regulation of the Level of Lake Erie.
Chas. V. Seastone, A Measuring Tank for a Jet Meter.
I. O. Baker, Fallacies in Good Road Economics.
J. H. Warder, 13 Pamphlets.
Chief Bureau of Yards & Docks, Annual Reports for years 1898 and 1899.
Otis F. Clapp, Annual Report City Engineer, Providence, year 1899.
American Institute of Architects, Quarterly Bulletin, April, 1900.
John Crerar Library, Fifth Annual Report, year 1899.
Engineering Dept. University of Wisconsin, Transcontinental Triangulation along the Thirty-Ninth Parallel, by John F. Hayford.
Board of R.R. Commissioners, Massachusetts, 31st Annual Report, January, 1900.

Journal of the Western Society of Engineers.

VOL. V. AUGUST, 1900 NO. 4.

XCVI.

RESERVOIRS AND THE CONTROL OF THE LOWER MISSISSIPPI.

By James A. Seddon, M. W. S. E.

Read June 20, 1900.

Perhaps the first comprehensive idea of river improvement that suggests itself is always that of a reservoir system, though of course at the beginning more or less river work may be carried on without any comprehensive ideas whatever. Cutting a canal around a rapids to extend navigation into upper reaches; the protection of an eroding bank that is threatening to destroy the wharfage of a city, or dredging a channel through a bar that is a serious obstruction at low water,—are all simply immediate efforts to remove local evils; and even when these go further and the banks are protected and suitable dykes are built so that the low water bar will not again form in that place, it is still open to the question whether after all it is not much the same as what in medicine might be called treating symptoms—doctoring the pain but leaving untouched the real ill which caused it.

Whatever, then, may be said for or against proposed reservoir systems—and, as it will be seen, in cases, much may be said against them—they yet have the merit at least of raising the thought above the limits of simply local works, which may or may not be river improvements. The idea is a fundamental one that the ills of the river in the main lie in the variations of its flow—with a destructive flood at one season, and not enough water in it for navigation at another—and to equalize the flow is the first, if not the only, step required to making the best of the river.

While this primary idea is a very comprehensive one, and the longer the ills of rivers are studied, and the better they are understood, the more certainly are they traced finally to this cause, still it is at the same time a very simple one. To hold back the excessive volumes of the floods in reservoirs, to be returned to the river when it has reached its lower stages, probably strikes every one at first as an immediate and complete remedy. Popular science also has built up on the same foundations a number of plausible deduc-

tions, where the rivers are taken as becoming worse or better as nature is assumed to be working on these lines to a greater or less extreme in flood discharges. Cutting down forests, draining lands, reclaiming swamps, with all the climatic changes that are assumed to go with such development of a country, are each and all given a place in these deductions, and that some of them actually have a place in the flood regimens is possible; but what this is, and what its magnitude and, indeed, even whether in a given case it would increase or decrease the flood extremes, is in general beyond the range of our present knowledge of the subject.

Thus taking the simplest case, that of a complete drainage system covering a large agricultural area: there is no question but that its action is to run off the rainfall more rapidly than it would pass into the river in a state of nature; but whether this would increase the flood extremes there or not would probably depend upon whether it ran out before the crest of the flood from above reached that locality, for if, in general, the flood from above arrived later, the retardations of the natural drainage system would be the condition that would tend to combine to give the greatest flood extremes there.

With the action of the forests on the run-off still a matter of speculation; little really known of the different effects as between the farm land and the prairie; many of the popular impressions in regard to climatic changes not as yet borne out by our meteorological observations, and even the simple case of tile drainage, while known in its action as yet unknown in its combinations with all the other contributions to the river, it is plain that this is no field for such general deductions. The questions in it are special questions of fact, and while the data can certainly be taken to settle all of them in general they have not yet been taken to settle any of them.

The effect of reservoirs on a river system is in much the same way simply a question of fact. Where located at the head waters there is the same uncertainty whether the water stored in them is that which would combine to make the destructive flood below. And where the flood below is a combination of several rivers, as it is in all the main waterways of our intercontinental drainage system, the question practically gets beyond the theorist. Each case is to be settled only in a special study of its data, and that only in so far as the data have been taken to determine it.

It is true, however, that, unlike the natural influences before noted, the reservoirs are under intelligent control. They may come in time to be operated so as to withdraw the flood waters at such periods as experience shows on the whole will produce the best results; and they may be very generally run out on the low

waters about when they are most needed. And while certainly their contributions to the low waters may not amount to much, where long low water periods are the ordinary conditions of the rivers, still such contributions are never really lost and their good effects may very possibly have been so far underrated.

For both of these reasons, in estimating the effects of reservoirs this question of efficiency that lies in their operation may for the time be omitted. Laying aside the doubts noted of how their withdrawal of a flood excess at one point will fit the combinations that make the flood below, it may be assumed anywhere that they take off from the top of the flood as much as they will hold, and their flood effects estimated on this basis—remembering that this is a limit that can never be altogether reached in any case, and may be very far from being reached where the reservoirs are located on the river a long way above the point where the flood is considered.

Then with this basis, for a system of reservoirs to prevent the overflow in any of the extreme floods of a river, or to reduce the flood to the level of the ordinary bank-full stage, they must be large enough to hold all the water that passes in the period of overflow, in excess of that which would pass in the same period with the river within the banks. Or, again, if a greater reduction was considered, say to two feet below the bank level, the flood excess which the reservoirs must hold is that which passes less that which would pass in the period with the river this two feet lower. This flood excess is a matter of the duration of the flood, or the number of days that it is above this assumed level, and the discharge capacity of the river for all the stages that it goes through on its rise and fall between this level and the top of the flood.

Again, the effect of a return of this to the low water period is the higher level that is maintained through the low water by the greater flow that this return gives it; and depends in the same way upon the duration of the low water and the discharge capacity of the river through these lower stages. Both of these effects, however, may be very closely estimated in any case where the discharge of the river for all these different stages has been well determined, each being the summation of given differences in discharge from day to day through the period, which as a whole is to make a volume of water equal to the capacity of the reservoirs.

But while such methods of calculating the effects of given reservoirs at any point of the river are simple enough (and any one may certainly go over the ground in this way from point to point along the river for different assumed reservoir systems, and for the different floods that follow each other from season to season, so as to fully cover the matter, and reach, finally, general conclusions that

he can count on as altogether safe) still it is not easy in the first place for him to so cover the matter as to fairly judge the subject; and, in the second place, after he has done so it is then almost as difficult for any one else to decide whether he has judged it correctly.

It is only in the method of directly showing all this matter that the question of reservoir effects becomes a comparatively simple one; not only for the engineer to form a correct judgment of it, but for anyone who cares to follow him to see that he has done so. It has long been the practice to show the flood regimen of a river by platting in succession the hydrographs from the head waters down. This hydrograph of the river, at any location where a gauge record has been kept, is made by taking a horizontal distance to represent the year and dividing it into the corresponding months and days, at each of which the gauge reading, or the level of the water in the river on that day, is plotted to a suitable vertical scale. The line joining these points, then, from day to day gives the hydrograph, which shows for that location in sequence all the rises and falls of the river through flood and low water periods of that year.

Taking one horizontal scale for the given year on which the hydrographs of the given gauges are plotted in order down, the whole flood regimen of the river is brought under the eye at once, and shows the magnitude of all rises and falls in the order of their occurrence. It does not, however, as yet show anything of that essential element in the reservoir question—the discharges of the river at all these different stages. For, of course, a rise of 25 or 30 feet is a very different thing in a river a hundred feet wide and in one a thousand feet wide; in the first, a given reservoir system may have the capacity to take off half the height of its average floods, while in the second its effects might be hardly appreciable.

To meet this requirement the showing of the discharge scales must be combined with these hydrographs. This discharge scale, at any point of the river, simply marks the levels from low water up for uniform differences in discharge just as the gauge scale is marked for uniform differences of level. This river discharge is generally given in thousands of cubic feet per second, the thousand cubic feet per second being taken as the unit in which the flow of these great waterways is reckoned. Taking, then, 50 thousand cubic feet a second as the uniform difference to be marked on the discharge scale, the first level above low water would be that of this 50 discharge; and this level drawn through the hydrograph would show at just what points in the year the river's flow had reached this discharge, with what periods and by how much it was above or below it, everywhere through the rest of the season.

MAP OF THE MISSISSIPPI DRAINAGE SYSTEM

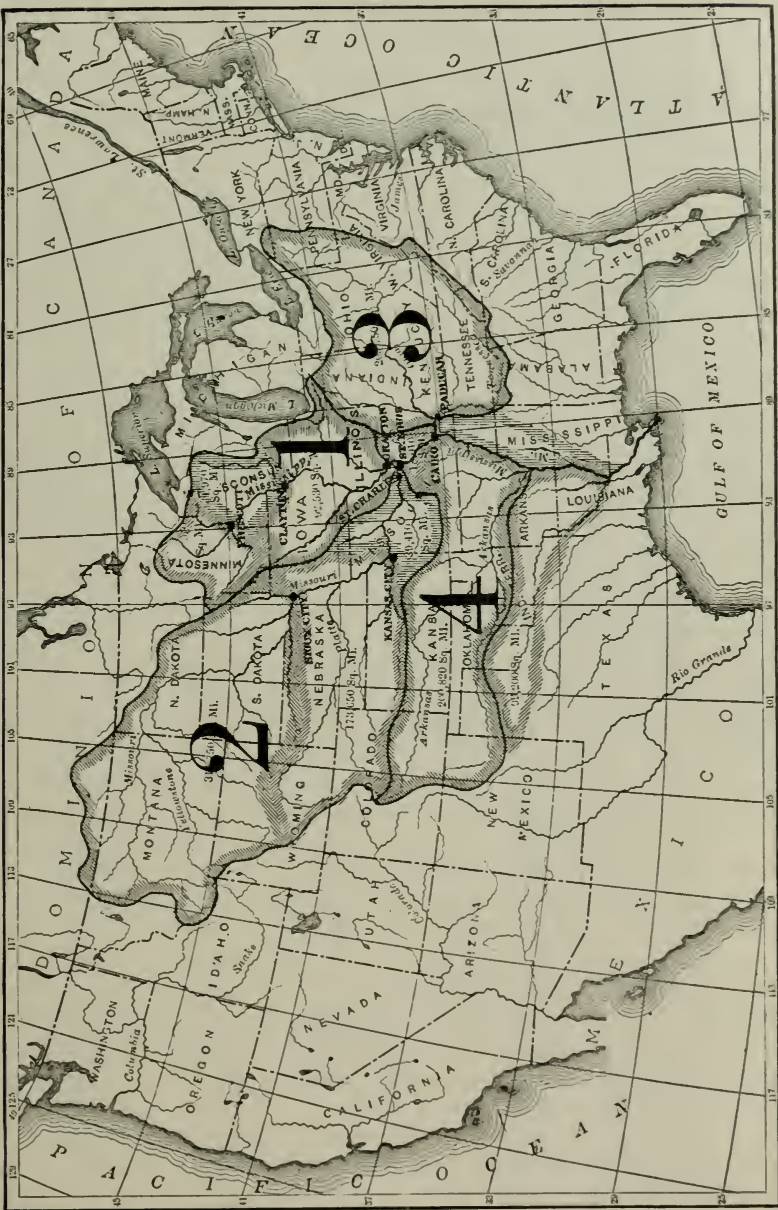


Fig. I.

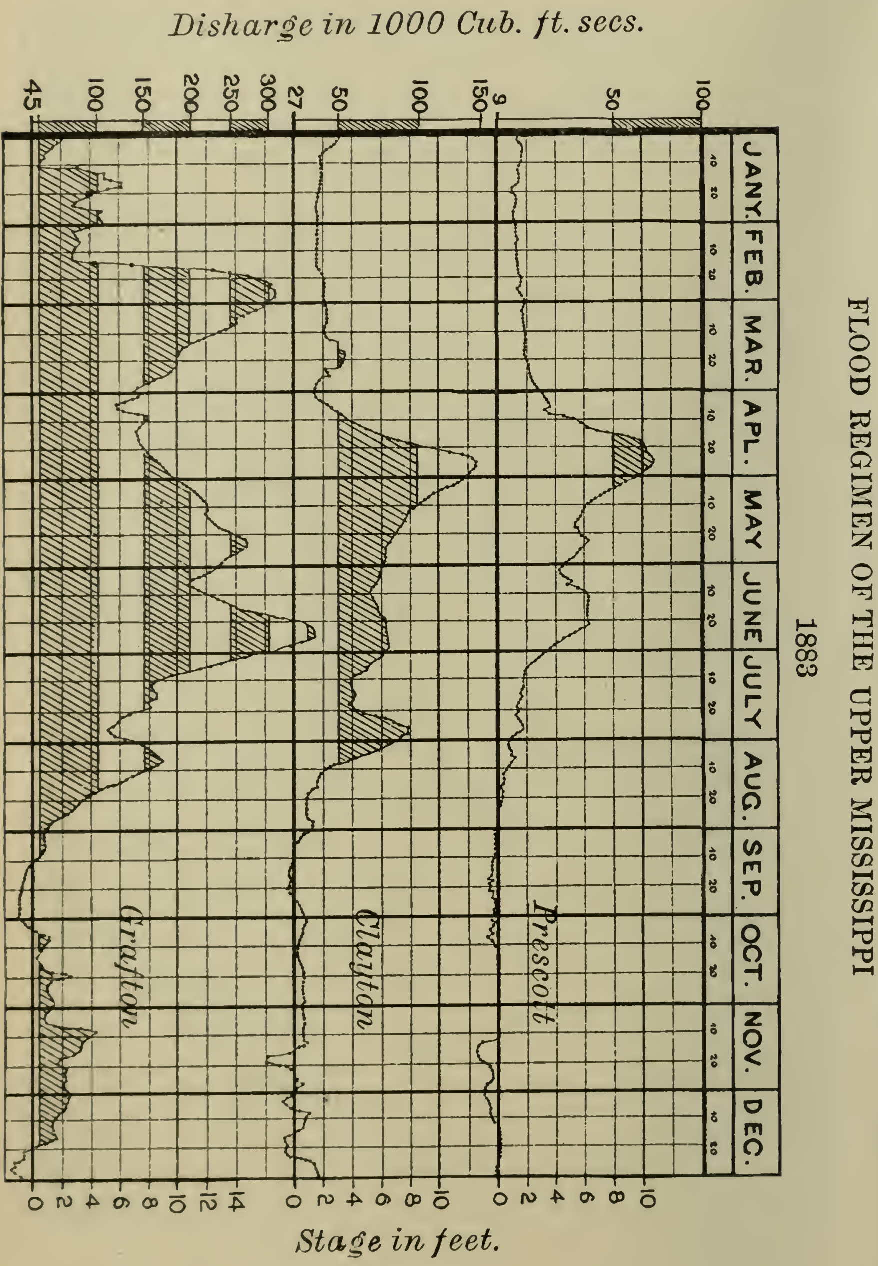

FLOOD REGIMEN OF THE UPPER MISSISSIPPI
1883
Disharge in 1000 Cub. ft. secs.
Stage in feet.
JANY.
FEB.
MAR.
APL.
MAY
JUNE
JULY
AUG.
SEP.
OCT.
NOV.
DEC.
Prescott
Clayton
Grafton

Fig. II.

The second of these 50 intervals on the scale marks the level of the 100 discharge in the river, and, drawn also through the hydrograph, shows immediately all the periods in which its flow is between this 50 and 100 value, while in general this interval on the scale is close enough for the discharge of any day in these periods to be read on this showing directly with sufficient accuracy. Continuing, then, this process from the low water up to the extreme flood level, and shading the alternate scale intervals for the convenience of reading the discharges through the hydrograph, the whole thing finally shows immediately, not only the sequence of stage through the year but also everywhere the discharge or the flow of the river that corresponds to it.

With this preliminary outline given, drainage systems and their combinations may now be considered. And, indeed, it is only in carrying these questions into the data of actual rivers that the problems can be fairly seen and the methods of determining them appreciated. The map, Figure I, gives the whole drainage system of the Mississippi, and on it the divisions that will be considered in succession are shown as 1, 2, 3 and 4, respectively.

Upper Mississippi System.

Division 1, Figure I, covers the Mississippi river from its head waters to its juncture with the Missouri, and is also here subdivided into the upper, middle and lower basins, the upper ending a little below St. Paul, at the juncture of the Mississippi river with the St. Croix and including the flow of that river. The middle basin covers the drainage from there down to below the mouth of the Wisconsin river, while the lower extends to Grafton and includes the Illinois river, the last of the tributaries above the Missouri. These subdivisions are taken to correspond with the series of discharge observations made by the Mississippi River Commission through the flood season of 1880–81, and known respectively as the Prescott, Clayton and Grafton series, and it is from these data that the discharge scales are determined which are taken in the showing of the Upper Mississippi flood regimen given on Figure II.

On this, as seen, the hydrographs of 1883 have been platted in order down for Prescott, Clayton and Grafton, at each point showing the water level of the river from day to day with all its sequence of changes through the season. The heavy lines at the bottom of the hydrographs are taken respectively at the levels of the ordinary low waters, and from this line as a zero the stage is marked at intervals of two feet by the horizontal lines above it, while the vertical lines mark the months and intermediate ten day periods.

The discharge scale begins at the discharge of this ordinary low water level, and above this the 50 level, the 100 level and the 150,

and so on are marked in succession. The 50 level is drawn through the hydrograph for all the periods in which the stage of the water is above it: the same is done with the 100 level, and the area lying between these two levels in each hydrograph is shaded. This marks distinctly the limits and the periods of this flow from point to point down the river, while in contrast the belt between the 100 and the 150 level is left blank, and again that from 150 to 200 is shaded. The top lines of each shaded area thus mark the alternate 100 discharge levels in succession and the bottom the alternate 50 levels.

With this it is in general easy to estimate the discharge quite closely at any one of these locations on the river, and at any period of the year. Thus, at Prescott the top of the April flood is something less than half the level between the 50 and the 100, and is not more than a 75 discharge at its highest, while at the same time the crest of the Clayton flood comes very nearly to the 150 value. But though the discharge of this flood at Clayton is about twice as large as it is at Prescott it is still very plainly the same flood, only swelled by the contributions of the tributaries between these points to double its flow by the time it reaches Clayton. But between Clayton and Grafton it is equally plain that its character as a distinct flood is wholly obliterated.

True, all the water that passes in the river at Clayton must be found after an interval passing in the river at Grafton; but in this case the contributions to the river from the lower drainage basin make the main flood at Grafton, and come in to give a high water there at a wholly different period. As a fact, however, the crest of this flood from Clayton is here indicated in the stand at Grafton about May 10 with discharge of 220; which makes a lower contribution of 70 to the 150 discharge from Clayton. But even with this contribution it is still but little more than a medium stage at Grafton, while the main floods of the year occur there about the end of February and the end of June, or some 70 days earlier and 45 days later, with discharges of 300 and 350 respectively.

In all this, however, it is not necessary actually to read off the discharge values to reach such conclusions; the whole thing strikes the eye at once in the first glance at it. Bearing in mind the fact that the height of these intervals of alternate shading within the hydrographs represent everywhere equal discharges, and that their breadth or extension on the time scale is the period that they hold in the river; they simply give a correct view, in true proportions, of all the flood volumes and their sources. Thus, the small fraction at Prescott of the shaded area above the 50 discharge level is placed, as a whole, in contrast with the much larger showing at Clayton below it; and the relative magnitudes of the two floods with the

Clayton excesses are everywhere just as distinct as the areas of a square foot and a square yard placed side by side would be.

In this way it is seen directly that all the flood waters to the end of March at Grafton come in from entirely below Clayton, this upper river being but little more than an ordinary low water stage; or less than 50 of the 300 extreme discharge which the flow at Grafton reaches at the end of February. Through April again the whole river is rising, together with the large contributions, however, from basin to basin before noted. Following this the decreasing flow from above is more than balanced by the increasing contributions from the lower basin, which reaches the extreme of some 250 discharge near the end of May, while again at the end of June the Grafton flow reaches 350, of which only about 80 comes from Clayton. And, finally, early in August there is a small rise shown that has its origin very clearly between Prescott and Clayton and marks about a ten day interval for the flood movement from there to Grafton.

This direct showing of the volumes of the floods from point to point down the river, in the first place, makes it clear where reservoirs would have effects. Thus it is plain that no reservoir systems above Clayton would have had any effect on the flood extremes at Grafton. The February flood, as before noted, comes in wholly from below and in the case of the June rise at Grafton, there would be no storage room left in the upper reservoirs had they been filled early in the season from the floods in their own localities; while, even if they had been kept empty for this contingency, it is very doubtful whether they could have reduced the flow from above just in the proper period.

In the second place, this showing also makes it simple and easy to estimate the specific effects of given reservoirs, or the dimensions of a reservoir system required to produce given effects. The unit of discharge, or the thousand cubic feet per second, is 86.4 millions of cubic feet in one day, or enough water to cover the surface of a square mile 3.1 feet deep. Taking, then, the reservoir surface in square miles and the depth to which it may be filled in feet, and expressing its capacity in the product of these two, or "square mile feet," the equality between any part of these floods and such a given reservoir capacity is quickly estimated. Thus the flood at Prescott above the 50 level is approximately a 20 discharge for 12 days and is therefore $3.1 \times 20 \times 12 = 744$ square mile feet—a reservoir area of 74.4 square miles if the average depth to which it could be filled was 10 feet; or, if filled to 20 feet depth, the half of it, or 37.2 square miles.

In this case it is also seen that such a system of reservoirs would cut down the level of the flood at Prescott some 2.6 feet, but when

run out again on the long low water of about 150 days following it, they would only contribute an average discharge of $\frac{744}{3.1 \times 150} = 1.6$ to the low water period. This would raise the river but little more than three-tenths of a foot through the low water period; and it is in such cases that a reservoir system may have quite a marked effect on the flood stages with little to speak of on the low waters that follow them. But it is easy to see that the case might be quite different at Grafton where a reservoir system that would materially reduce the floods of this season might be used to raise the extreme low water stages by several feet.

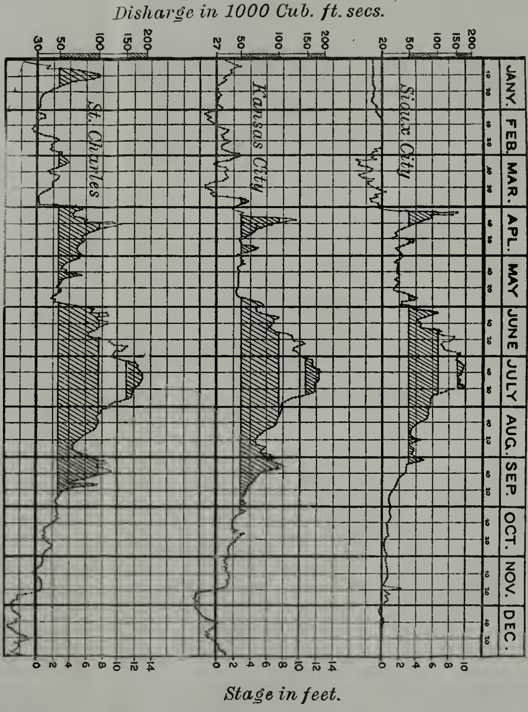
This will serve as an outline for the Upper Mississippi. Of course a full study includes the consideration of a number of flood years and a showing of their volumes at a number of intermediate locations, but what has been given is enough to bring out the general features of this drainage system, which is specially interesting in view of the fact that one of the largest reservoir systems of the world has been constructed above Prescott on the head waters of the Mississippi.

In the series of lakes that lie at these head waters, a great reservoir capacity is cheaply gotten; and, as a fact, the reservoir system constructed there can rarely be much more than half filled. But whether they could be filled or not, it is well to see that even at Prescott the low water of the river could never be raised to any great extent by them, while probably these effects would hardly ever be seen in the stages below Clayton. Above the St. Croix and the Minnesota rivers, of course, the low water effects would be some two or three times as great and might show a distinct improvement to the navigable depths there; while their effects on the flood stages of this extreme upper river is doubtless considerable.

The effects of these Upper Mississippi reservoirs, however, hardly touch the field of this study. The whole basin above Prescott gives but a small part of the final flood from this river, and the fraction of that which is under the control of these reservoirs must be left for more detailed studies. They probably have some effect on the extreme flood stages as far down as Clayton, and on the low water navigation above St. Paul, and very certainly furnish a substantial addition to the water powers of Minneapolis; but so far as any practical effect on the river at Grafton is concerned they might as well be located in the desert of Sahara.

Missouri River System.

The Division 2, Figure I, gives the drainage system of the Missouri, which is also subdivided into the upper, middle and lower basins. As, however, in this case Sioux City is as far up as the requisite discharges have been taken, the upper basin here gives a



FLOOD REGIMEN OF THE MISSOURI

1880

flood made up of more combinations and much further from the head waters than that of the like case on the Upper Mississippi. The two studies, however, cover about equal reaches, and, as it is more or less definitely known that the Missouri is much the same river for some five or six hundred miles above Sioux City, the marked difference in the character of its flood regimen over such a distance is a matter to be specially noted.

This is seen at once in the showing of its flood regimen on Figure III. There, for the year 1880, the hydrographs are given, in order down, for Sioux City, Kansas City and St. Charles, while from the level of the ordinary low waters at each point the discharge scales are marked and the alternate intervals shaded through the period as in the case of the Upper Mississippi. But unlike the case of that river, the volume of the main flood here shows little or no increase along its whole course. Thus the top of the July flood averages about 160 discharge at Sioux City and hardly more than 180 at St. Charles, some 800 miles below; while nearly all this 20 difference shows between Sioux City and Kansas City, and is probably also snow water from the head waters of the Platte river.

Head water reservoirs in the upper basins of the Missouri may thus be expected to have a much more marked effect on the floods along the whole course of the river than they could possibly have on such a stream as the Upper Mississippi. And as all this waste water is also badly needed in the arid regions for purposes of irrigation, they have certainly equal, if not better, claims on the government for their construction.

In the long low water periods their effects at best on that stage would not be material, and their service simply in the demands of irrigation would not conflict with any practical results that might be aimed at in the return of their stored waters to the river. However, 1880 is quite a low flood season that was selected simply to mark this contrast between the Missouri and Upper Mississippi most distinctly.

For the extreme flood regimens of the Missouri, Figure IV is given, which shows two of its greatest floods, differing most essentially in their character. Thus, the 1883 flood is below the ordinary high water at Sioux City, with discharge something under 150, but it receives a large addition to its volume from the second basin, reaching an extreme at Kansas City of over 400, which is again increased by the contributions from the lower basin to a discharge of something more than 550 on its crest at St. Charles. On the other hand, the crest of the great flood of 1881 is distinctly over the 500 discharge level from Sioux City to Kansas City, while actually something under this at St. Charles; and thus absolutely its whole

flow comes simply from head water contributions altogether above Sioux City.

The effect of head water reservoirs on the flood of 1883 of course corresponds more nearly to the case of the Upper Mississippi. In the basin lying between Sioux City and Kansas City, and covering mainly the Platte and the Kaw river drainage, reservoir systems could probably be filled directly with water that would otherwise go to swell the flood crest in the main river, but in the Sioux City basin they would have to be so operated as to reduce as far as possible the flow from above just in this lower crest period, and how far this could be done so as to reduce the extreme stage in the lower river, is one of those questions of intelligent operation that is a matter of trial and experience.

On the other hand, the flood of 1881 has no such questions in sight. It is known, however, that a large part of this main flood came from below the Yellowstone, and the distribution of the reservoirs in this upper basin, to have taken off its excess directly, is still to be settled. But assuming that the reservoir system there was located to do this, there is no further question for the rest of the river; to cut off the crest at Sioux City is to cut it off all the way down.

For an estimate of this, taking it in round numbers, between t 400 discharge level to the crest, the volume is about 100 discharge for 6 days, and between the 300 and the 400 level it is about 100 discharge for 10 days. Altogether, then, the flow above the 300 discharge level was: $3.1 \times 100 \times 16 = 4960$ square mile feet; or, say, it would take 248 square miles of reservoir surface 20 feet deep to hold it. This would have lowered the flood stage on an average some 5 feet along the whole river, and probably have rendered comparatively harmless the most destructive flood that has occurred since records have been kept on the Missouri.

It should be noted here, however, that such estimates are only approximate values, and especially so for the upper part of the Missouri, where no actual discharge observations have yet been made at any such extreme high waters, and the discharge scales are simply carried up to these levels with rates given by the observations at lower stages. But even where the levels are actually given by observed discharges in such rivers as the Missouri, it is equally well determined that from time to time they may differ materially.

There are a number of elements that contribute to this variation in the level of a given discharge. For instance, such a river may cut across a bend, altering its whole course and greatly reducing its length in that vicinity, with the level of a given discharge permanently changed there. And, indeed, after such a change, no discharge scale should be used for that location until a correct one

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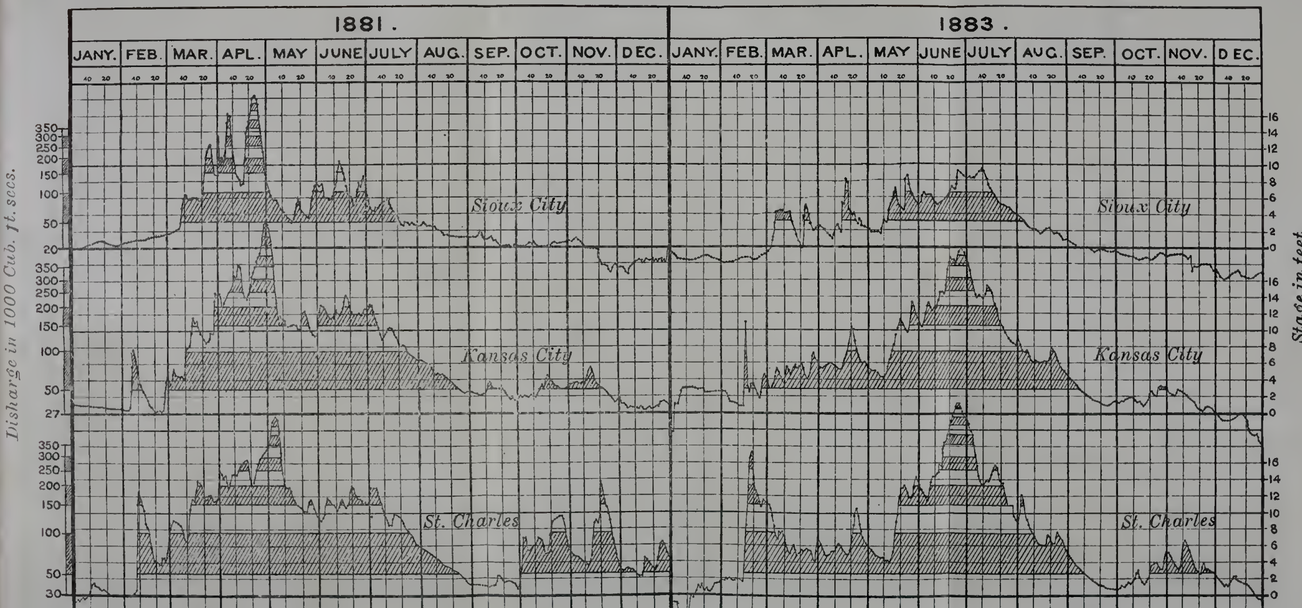
EXTREME FLOOD REGIMENS OF THE MISSOURI



could be re-determined for it. But, even where there are no such apparent changes in the character of the river, it is found that the level of the discharge scale is at best but a mean between limited rises and falls of the actual level of the given discharge from flood to flood and from season to season.

These variations in the discharge level run through periods, and change from above to below the given mean and back again, from causes that are as yet only partly understood; but as a fact in each they are in general very fairly covered by simply shifting the mean discharge scale as a whole up or down, as the case may be, from a tenth or so to the better part of a foot in any one of the periods. This is instanced on Figure IV, in the 1881 flood regimen of the Missouri. Through the whole time there, from the end of May to the end of September, the scales given show a larger discharge throughout at Kansas City than that passing St. Charles in the same period.

Such differences for a few days may be caused by ice gorges in the spring break-up, and they are also possible on the sharp crests of extreme high waters that flood the whole valley; but in ordinary conditions and through extended periods all the flow past Kansas City must show past St. Charles, with such additions as may come in from the tributaries between them; and the difference here given simply makes it plain that either the Kansas City mean scale is too low and its discharge showing too large, or, what is more probably the fact, that the given St. Charles scale is too high, and its discharge showing too small for the period. Thus, if the St. Charles discharge scale was put down altogether to about eight-tenths of a foot lower level, it would show through the whole period a fair degree of consistency in the amount of water passing from Kansas City to St. Charles.

On account of this apparent shifting, as a whole from time to time, of all the flow levels of the river at the given locality, this phenomenon of variation in the discharge levels has been given the general title of "change of plane," and in what follows will be so referred to. Thus, the mean discharge scales represent normal planes while the case of 1881 on the Missouri, just cited, is a plane lowered 0.8 foot at St. Charles from May to September; and in alluvial rivers it should be distinctly understood that the normal plane is simply a general equilibrium around which the varying levels of the different floods and seasons oscillate.

It is coming at the same time to be understood as well that the alluvial river in its form and dimensions is also simply an equilibrium between the erosive and bar building forces that its flow and its variations of flow give it. The erosion is well marked and fairly estimated by the average amount of bank that caves in annually;

and this, on the Missouri between Kansas City and St. Charles, is a width of over 70 feet a year along the whole length of that river. This, dumped into the deepest part annually, is an amount that would fill it up solid to some 12 feet above low water in the 20 years the government has been working on it, were it not for the fact that it is cleared out annually by the bar building forces of the flood period.

In the play of such forces, with their extremes of action not at all coincident in the yearly cycle, it is not surprising then that the discharge levels are from time to time shifted; and in more detailed studies, following the flood from gauge to gauge along the river, many of these changes of plane may be detected. But for taking the flood volumes on an average, from year to year, and from point to point along the river, these normal discharge scales answer the purpose. And, indeed, it is only as they do this that they are correctly determined.

Middle Mississippi and Ohio Combinations.

Aside from actual discharge observations, however, it is really in the combinations of rivers that these average or normal discharge scales are best tested. Taking, for instance, the Missouri at St. Charles and the Upper Mississippi at Grafton, their combined flow is necessarily just that of the Middle Mississippi at St. Louis. The summation of their scale discharges at any time will then give the St. Louis showing if it has the same plane; if, however, there is a different plane at any of these points, its difference will be marked by the discrepancy in this comparison.

Following this matter through a number of years in this way, here and there quite marked changes of plane may be detected. But, on the whole, the general agreement of the St. Charles and Grafton floods with their summation in the St. Louis flood regimen is really quite striking. For illustration, Figure V shows this combination for the year 1882.

The St. Charles and Grafton scales mark this difference in discharge as given on former plates, but for the showing at St. Louis a 100 difference for the marking of its scale is taken. The heavy line of ordinary low water at St. Louis, on which its discharge scale begins, is of course the sum of the low water flow from St. Charles and Grafton, and from there up its scale marks the levels of this doubled difference in the discharge, to correspond with this natural summation in the rivers. Thus, the top of the first shaded area at St. Louis is a 200 discharge, and corresponds to the top of the first shaded area at both St. Charles and Grafton, or the level of a 100 discharge from each of them, and so on up for the higher discharges.

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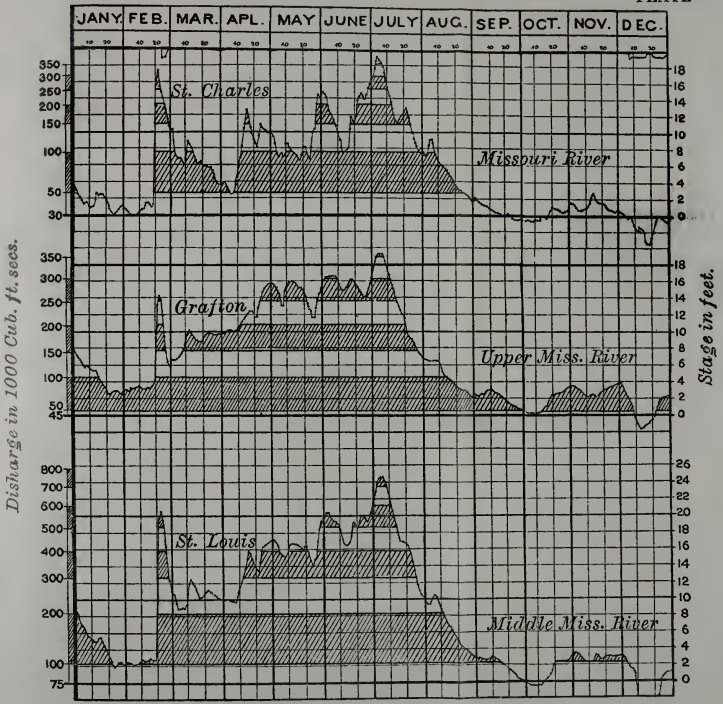
Vol. V, No. 4.—Fig. V.
Seddon—Reservoirs and the Control of the Lower Mississippi.

1882

FLOOD COMBINATIONS

St. Charles and Grafton equals St. Louis.

PLATE



With this, the flood year is quickly checked over. Thus in the low water the last of January, the showing of St. Charles and Grafton is somewhat large for St. Louis; or St. Charles about 30 and Grafton about 80, while St. Louis shows but a shade over the 100. This however, is in the period when the rivers are generally frozen over and during which the discharge scales can not be counted on. But on the break-up following it, February 20, the agreement is very close; St. Charles at the crest showing 300 and Grafton 250, with St. Louis crest just the sum of these, or 550. Through March, St. Charles falls and Grafton rises, holding an average of about 250, which, April 8, shows 50 from St. Charles, with a little less than 200 from Grafton, making about the 240 given at St. Louis. Next the crest of May 1 is, St. Charles 140, and Grafton 290, giving the sum of 430 shown on the St. Louis crest; and again the crest early in July of 350+ at St. Charles and 350+ at Grafton, makes the something over 700 at St. Louis. From this on there is a general fall till early in October, when the rivers all reach the ordinary low water level together, or a 30 St. Charles and 45 Grafton discharge, giving the 75 ordinary low water discharge of the Middle Mississippi. And, finally, rising with an average of 35 and 75 through November, they give the 110 average of St. Louis; after which the rivers freeze over and the irregular showings of the ice period begin.

Now considering the volumes of flow dealt with through this whole season, the possible discrepancy in these summations really shows an extreme small percentage of error in the use of these normal discharge scales. It, however, should be here noted that it does not follow that they give the actual values of discharge from day to day with the same precision. In the matter of changes of plane, for the lower rivers at least, a larger discharge on the front of the flood and a less on the fall is a common phenomenon; while at any time actual discharges say in excess, 20 at St. Charles, 20 at Grafton and 40 at St. Louis, would show no discrepancies on these scale values.

So far as this coincident change of plane is common to the three rivers, larger discharges on the rise and less on the fall may occur without showing any contradictions in these flood summations. And as also the rises and falls at St. Louis are the products of rises and falls at St. Charles and Grafton, some coincidence in changes of plane of this character may be expected. But in the volume of flow represented by the shaded area between any two of these discharge levels, the river has as much rise as it has fall in it; and for that, at least, these discharge scales should give the total flow in true proportions, in so far as they agree in these summations.

With what has been given it is, of course, plain that any effects of head water reservoirs on the flood stage of the Middle Mississippi depend solely upon whether the crest of the St. Louis flood coincides with the flood from the Missouri; for it has been seen that reservoirs at the head waters of the Mississippi have no effects whatever on the flood stages at Grafton. This coincidence in the St. Charles and St. Louis flood crests shows in this year on Figure V; and, indeed, this is very generally the case in the extreme floods of the Middle Mississippi; so that whatever reservoir effects can be brought down the Missouri to St. Charles come at the right time to reduce the floods at St. Louis.

But it will be noted as well, that the flood at St. Louis is that of a doubled river, and the reservoir water withdrawn from the Missouri crest will not show a like reduction in stage when taken from the top of the flood in the Middle Mississippi. This is not a matter of close estimates, as it depends more or less on the combinations, but approximately it may be said that reservoirs on the Missouri that would in general reduce the flood stages at St. Charles some five feet could hardly be counted on for more than a three foot reduction in the flood stages at St. Louis.

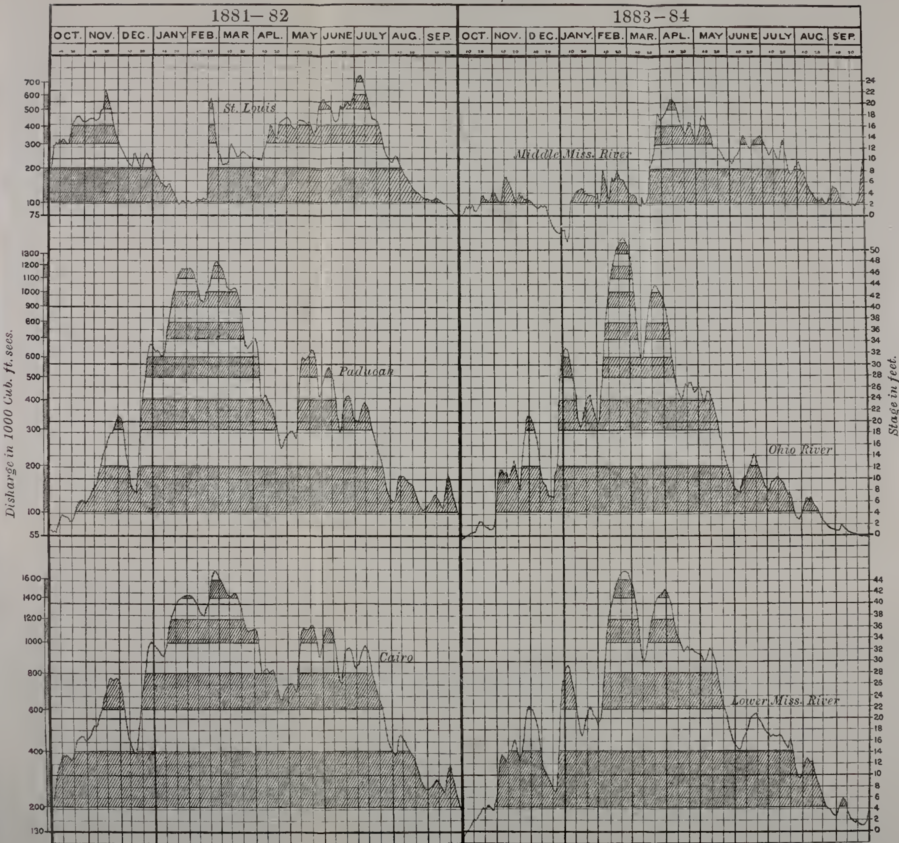
However, any reservoir effects that may be brought down to the Middle Mississippi again entirely disappear when it comes to the combination of that river with the Ohio. The total drainage system that contributes to this great flood of the Lower Mississippi is seen on Figure I, and the combination of the Middle Mississippi and Ohio rivers that make up its flood regimen for 1882 and 1884 respectively, are given on Figure VI.

Here the Middle Mississippi is given as before by the flood regimen at St. Louis, and the total flow from the Ohio basin (Division 3, Figure I) by the flood regimen at Paducah, 45 miles above its mouth, data for its subdivisions not as yet having been taken. On each of these the scales mark from low water up the levels of 100 discharge intervals, while their combined flow, shown in the Cairo stage close to their junction, is marked as before with the doubled scale interval, and corresponds to the sum of the equal 100 levels from the Middle Mississippi and Ohio. Thus the top of the first shaded area is a 200 discharge at St. Louis, 200 at Paducah, and the sum of the two, or 400, at Cairo, and so on for the higher levels.

In these combinations it is seen at once that the flood in the Lower Mississippi comes mainly from the Ohio river. True, in 1882 a short rise from above happened to coincide with the crest from the Ohio and adds something to the extreme stage at Cairo; but the total contribution of flood water from the Middle Mississippi is even in this case relatively insignificant, while in 1884 about the

FLOOD COMBINATIONS

St. Louis and Paducah equals Cairo



same extreme is reached at Cairo with St. Louis at little more than an ordinary low water stage. Any head water reservoirs, therefore, that would affect this extreme must be located in the Ohio river basin and draw off the flood waters of that river.

This main flood from the Ohio may be looked for at Cairo about the end of February, while the spring rise of the Missouri in general comes in April, and the regular June rise some two months later and, combined with the Grafton flow, forms the flood at St. Louis. With this wide interval, then, of some two to four months between the high water periods, and the much smaller volume of the St. Louis flood, even the extreme high waters there have but little chance to affect the flood stages at Cairo, and however great the reservoir control of these upper rivers might be, and however large their flood reductions, about the same extreme floods in the Lower Mississippi would still come, as they have always come, from the Ohio.

Reservoirs in the Ohio river basin have long been proposed for the control of these high waters, and again such control from time to time has been reported impossible. But it may be here noted that the data have not yet been taken to determine in any definite way just what effects such systems of reservoirs might have on the final flood of that river. From the cases given for the Upper Mississippi and Missouri it is plain that to settle such questions the flood volume must be traced back to its sources, and beyond the 1882 series of discharges at Paducah practically no observations on the flow of this river are given. While, of course, it would be more satisfactory to show definitely in this case also the possible effects of head water reservoirs, it is not, however, a very difficult matter to conclude that, taking them at their best, little relief can be looked for from this source when the immense volume of the flood here is considered.

And, indeed, it may be stated generally, that the cost will not warrant the construction of head water reservoirs simply for the control of the river. It is only as they are a substantial addition to valuable water powers, as in the Upper Mississippi, or where their water is badly needed for irrigation, as in the case of the Missouri, that they have a claim to be considered.

Lower Mississippi.

Natural and Leveed Regimens.

But while the Lower Mississippi is practically out of the reach of effects from reservoirs at any of its head waters, still in its natural condition its alluvial valley presented a most striking instance of a great reservoir system of its own. Figure VII is a map of the

river from Cairo down, the shaded portion showing this area subject to overflow in high waters—in all about 30,000 square miles, or some three times the area of Lake Erie. This, in the main, is formed into a series of great basins. Upon the west bank, from Cairo to Helena, lies the St. Francis basin, while the Yazoo extends from Memphis to Vicksburg on the east. Below the bluffs at Helena, on the west, lies the smaller area known as the White River basin, ending a little below the Arkansas river, where the Tensas basin begins, extending down to Red river. Below the Red river, on the west, the overflow area is known as the Atchafalaya basin, and on the east, from where the bluffs finally leave the river, as the Ponchartrain.

In general, all along these basins, the ground slopes back from the Mississippi into an area of low swamps, threaded with lakes and bayous, and draining into such rivers as the St. Francis and Yazoo. Thus, as the Mississippi rises above the bank-full stage the flood excess is drawn off into these swamps, which act so far just as a system of great reservoirs. As, however, all the upper basins have their natural drainage back into the Mississippi, it is only above this return that the reservoir action is complete, while at their lower ends they do not hold but only retard the flood excesses that have been drawn off above.

This is the natural condition of the Lower Mississippi. However, during the last 15 years the States and Government combined have built up a levee system for the protection of these swamp lands, that now entirely shuts out the overflow from all but the upper one of these great basins, and that is beginning to seriously restrict it in that.

This levee system is shown on Figure VII in the heavy broken lines next the river; and, in order up, may be noted as follows: On the east, the line from the bluffs at Baton Rouge to the gulf shuts out the overflow from the Ponchartrain basin, while the line on the west, from below Red river down, closes the Atchafalaya. Above this, on the west, the line from a little below the Arkansas river nearly down to the mouth of the Red river shuts out the overflow from the Tensas basin, while on the east the line from Memphis to Vicksburg closes the Yazoo. The line from the bluffs, at Helena, nearly down to the White river closes the front of the White river basin, but, on account of the much smaller dimensions of this basin, at high stages it is necessarily more or less filled with back water from the Mississippi, and it is further subject to heavy overflows from floods in the White and Arkansas rivers.

All this then leaves open only the large basin lying on the west, between Cairo and Helena, and known as the St. Francis basin, while the levee, now in part closing this, is shown in the line ex-

ALLUVIAL VALLEY MAP OF THE LOWER MISSISSIPPI

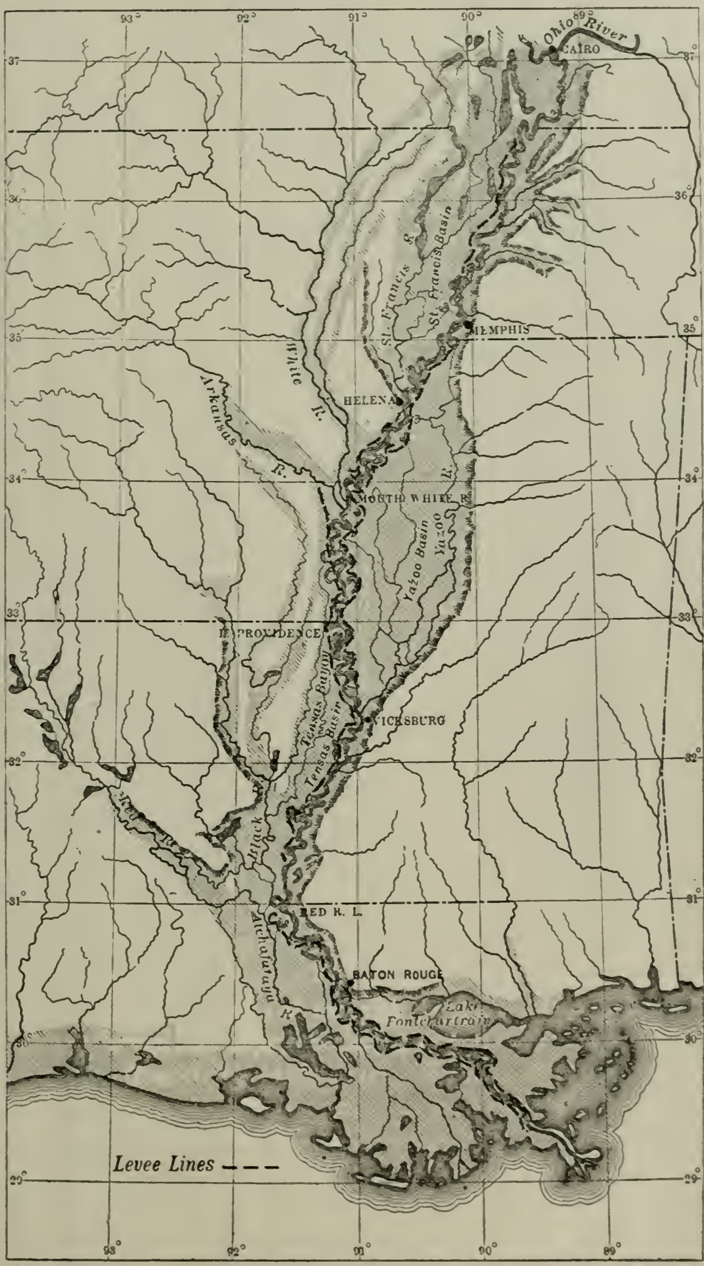


Fig. VII.

tending from the high ground at New Madrid down to a little above Memphis. This line, as first built, was much too low to withstand the increased flood heights that followed the restricted overflow, and the great flood of 1897, the first that has come against it, broke through the levee in a number of places before it had reached its extreme by several feet. But it, nevertheless, gave the last and the best indication of what flood heights may be expected when the overflow into this natural reservoir system is entirely closed out.

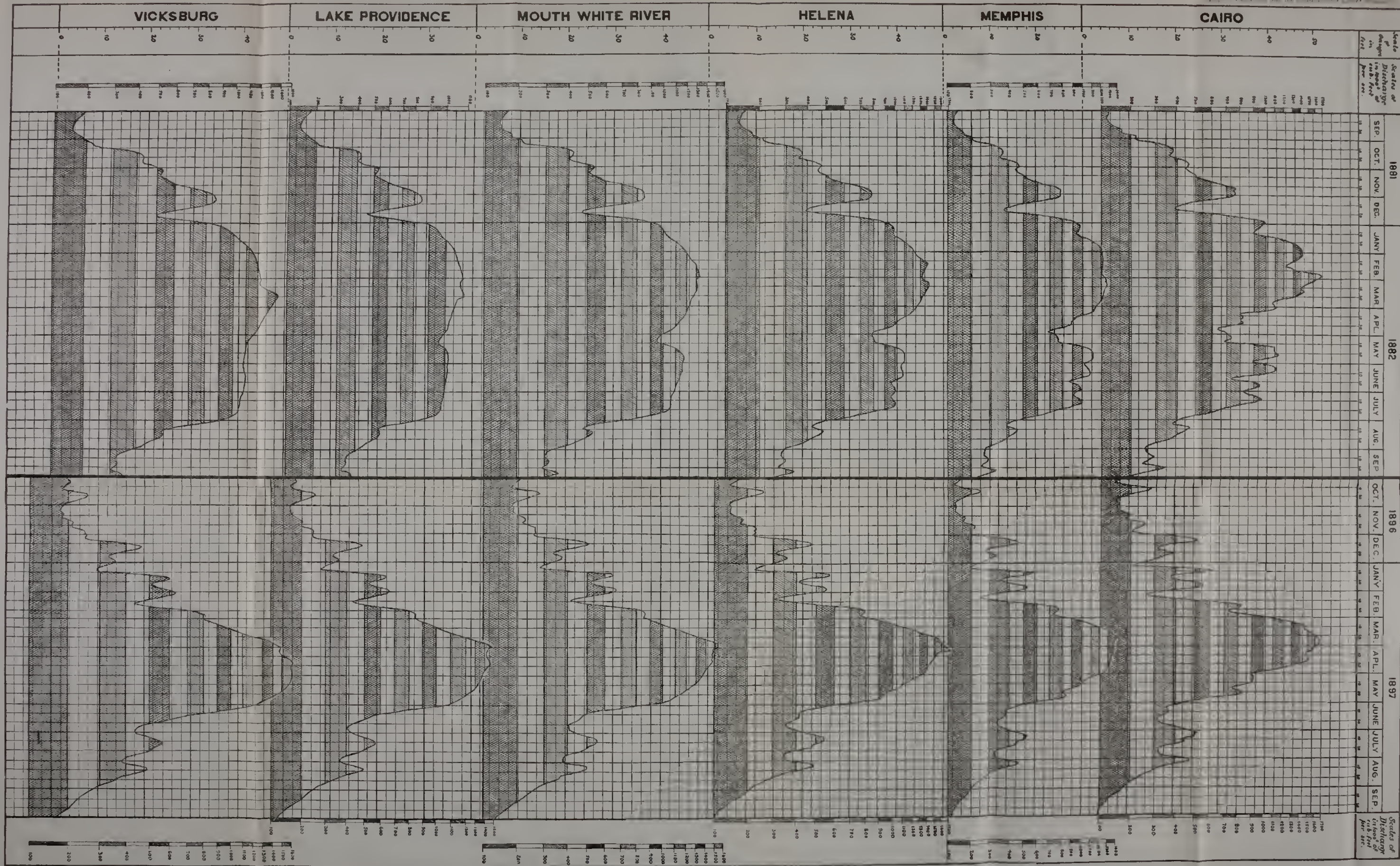
Figure VIII presents this contrast in the regimens from Cairo to Vicksburg of the great floods of 1882 and 1897, the first a condition of free outflow and inflow, and the second the condition of levee restraint above noted.

The scales in this case uniformly begin at the level of the 100 discharge, and mark the levels of successively increasing 100's up to the extreme high waters, while the shading here is again alternated with a cross-shading to show the levels of the same discharge all the way down the river as distinctly as possible.

The general character of the free outflows and inflows may be first noted in the 1882 flood regimen. The spill over the banks into the swamp basins begins to be marked at about the level of the 1,000 discharge or some 12 feet below the extreme stage of this flood at Cairo, which reaches there to about the level of the 1,700 discharge. This, however, is cut down by the outflow into the St. Francis basin to but little over the level of a 1,200 discharge at Memphis, while again the flood is brought back by inflow to the level of a 1,400 discharge at Helena in two crests corresponding with the Cairo crests, only some 12 or 14 days later.

It must be understood that these are but average discharge levels, while the actual extreme discharges of the flood may be materially larger. This is especially the case from Helena down where, between the draw of a free outflow on the one hand and the lake-like character of points in a complete overflow on the other, wide differences are found in the discharge at the same level in different periods. The inflow shown at Helena also in this case is clearly not the total inflow, since the outflow into the upper Yazoo at the same time is necessarily lost to the Helena stage and discharge.

Below Helena the flood waters from the Arkansas and White rivers, draining Division 4, Figure I, combine to make the conditions even more complicated. But the fact that the outflow here exceeds these contributions shows in the reduced discharge level of about 1,300 at the mouth of White river. And again, from there to Lake Providence, the double outflow into the Tensas basin on one side and the Yazoo basin on the other, cuts the flood extreme down to between the 1,000 and 1,100 discharge. While, finally,



LOWER MISSISSIPPI FLOOD REGIMENS
Natural and Leveed.

the return flow from the Yazoo basin brings the flood back at Vicksburg to the 1,400 discharge level, notwithstanding the simultaneous outflow into the Tensas basin, as in the case between Memphis and Helena.

But, even without the above analysis, the marked effect of this system of swamp reservoirs on the flood strikes the eye in the first glance at it. From January 1, the beginning of overflow, to the latter part of July, when the river again gets within banks, all the flood extremes at Cairo are planed off by the outflow, and all the lower stages between these extremes filled in with it. That the basins can not hold this flood water back for the low water period is plain; from ten days to two weeks is about the retardation of each of them, and in a flood period of months it must practically all come out again on it. But even where it comes out, this reservoir system has considerably cut down the extremes in its leveling up process, while at such points of maximum outflow as Memphis and Lake Providence, it has about relieved the Mississippi of one-third of its flow, and a great river of some 500 or 600 discharge is carried down in the swamps outside of it.

Now, in contrast to this free overflow in 1882, the flood of 1897, subject to the levee restraint before noted, is certainly most striking. With an initial flood at Cairo some 0.3 feet lower, from Helena down the extreme high water stage is raised from 4 to 6 feet—and this notwithstanding the fact that a good part of the St. Francis basin was yet open; while the levee that was there gave way when the river was still some 200 to 300 below its maximum discharge. And again the flood, from there down in succession, broke through the Yazoo, White and Tensas levee systems in a number of places, pouring a great volume of its excess through the crevasses into each of these basins.

The magnitudes of these outflows may be roughly estimated in the various discharge levels reached by the crest of the flood from point to point down. Thus, with close to a 1,700 extreme discharge at Cairo, only about a 1,400 discharge is reached at Memphis, which again is brought back with inflow to the 1,700 discharge at Helena. This, however, breaks through the levees there before it has reached its extreme, and draws down the stage to a marked degree; while the levee system below has broken even earlier at about the level of the 1,500 discharge, and all the flow in excess of this, with the flood waters of the Arkansas and White rivers, are drawn off through these crevasses. Of this the outflow into the Yazoo shows again in its return at Vicksburg, raising the river there to the 1,600 discharge and holding it up to about that volume till the flow from above has fallen to between the 1,300 and the 1,400 level.

Altogether, then, from the evidence of this 1897 flood, there is

little doubt that to shut off the outflow completely from all these great basins, is to raise the high water stages of such floods from six to eight feet above the levels at which the natural reservoir system of this river would have carried them; and even in the interests of a *real* flood protection alone, it would certainly be wise to consider whether some less dangerous step into the unknown might not be substituted for it.

This substitute suggests itself at once in the inefficiency of the natural reservoir compared with the one under intelligent control; especially when the extremely low efficiency of this system of swamp reservoirs has been recognized. Two weeks has been noted as about the longest period that these basins would hold back the outflow and their inflows again form destructive floods at the foot of them. But had the St. Francis basin in 1882 simply been cross leveed at intervals, with outlets under control, making of it a chain of reservoirs to hold this flood water, there would then have been no return flow at Helena, no corresponding outflow into the Yazoo, no inflow crest at Vicksburg; and, while there would still have been some overflow, yet from Memphis down there would have been no great flood that year, and certainly nothing that a very moderate levee system could not safely have carried.

It is true that, in this case, reclaiming the swamp lands in the back of the St. Francis basin would have to be given up—some 4,000 square miles as yet unprotected and undeveloped. But this swamp land is not the only land in the valley. Even after the closure of these great basins is complete, their lower ends are still flooded by back waters, and with the higher stages of the restrained floods, in the White river basin at least, this may affect a good per cent of it. In the same way the chain of small basins on the east in the narrow strip from Vicksburg to Baton Rouge, would be altogether flooded by back waters even if their fronts were protected by levees, and this covers some of the best alluvial land in the valley.

In the similar strip between the bluffs and the river from Cairo to Memphis, probably some levee protection can be given, but the complete closure of the St. Francis front promises to seriously flood a large part of it. And, finally, there is the strip all the way down between the levees and the river that, with all points and islands, is cut off from any protection. This land, of course, is deliberately condemned to bear the more frequent and heavier inundations for the sake of the protection afforded the land back of it, and is certainly but a small fraction of the total area protected.

But all this area that is directly or incidentally drowned out by the complete closure of the great basins is not a small fraction of the 4,000 square miles in the St. Francis that would save it, and,

as the first now is, in the main, farms while the second is almost wholly swamps, it is alone a nice question of how much of the one should be sacrificed for the other. But the question does not stand alone; considering the increasing risk that each additional foot to the high water stages throws upon all the land behind the levees along the whole valley, there is very little doubt that holding the flood waters back, once for all, at the head of the system and never having extreme floods is true flood protection, even if it does sacrifice some 13 per cent of swamp area.

Referring to the flood regimen of 1882, it is seen that a system of cross levees, barring the slope to the south of the St. Francis basin, in all some 120 feet, is simply to take the Memphis flood of that year as the extreme to be passed through to the gulf in the place of the Cairo extreme. There are good reasons for passing the initial flood through to the gulf between levees without any further alternations of outflow and inflow, but to take the Cairo flood for this is to take an extreme discharge of 1700, in the place of the 1200 Memphis extreme, or about some 500 greater discharge to drown out the land below which is cut off from a levee protection, while greatly increasing the danger to all that is protected.

A levee system with the Memphis flood as the initial one would then pass the high waters at something between the natural extremes found in the course of the unleveed river. Flood volumes at points of maximum outflow, such as Lake Providence, would be larger, and less at points of maximum inflow, such as Helena and Vicksburg. The corresponding bed changes would also lie between these extremes, while the grade of the river would not be broken by alternating reaches of excessively increased and reduced discharges.

The nature of these corresponding bed changes may be recognized in the changes of the discharge scales from the floods of 1882 to 1897. Where the levees have increased the flood volumes materially they have, in general, lowered the levels of the low water flow; the levels of the high water flow as yet show little change, except a small depression at Lake Providence. The increase in the flood extremes of a complete restraint, then, simply promises a marked increase in the range between the low water and the bank level; and as one of the most serious problems of the Lower Mississippi is the erosion of a river that rises and falls some 50 feet against banks of light alluvium, the bed changes in this case are certainly most threatening.

Indeed, this matter of caving banks on the Lower Mississippi is only second in its importance to the flood protection and in fact, the two are closely related. In long reaches the bank erosion has its annual average of some 125 feet, that year by year eats its way

into the levee line, and a new line has to be constructed back of it. And not only has the river a sure mortgage on the land adjoining it, but there are few of the towns and cities along its course that have not a more or less continued fight with this movement of the river, to hold their wharfage and front properties, in which the river finally conquers.

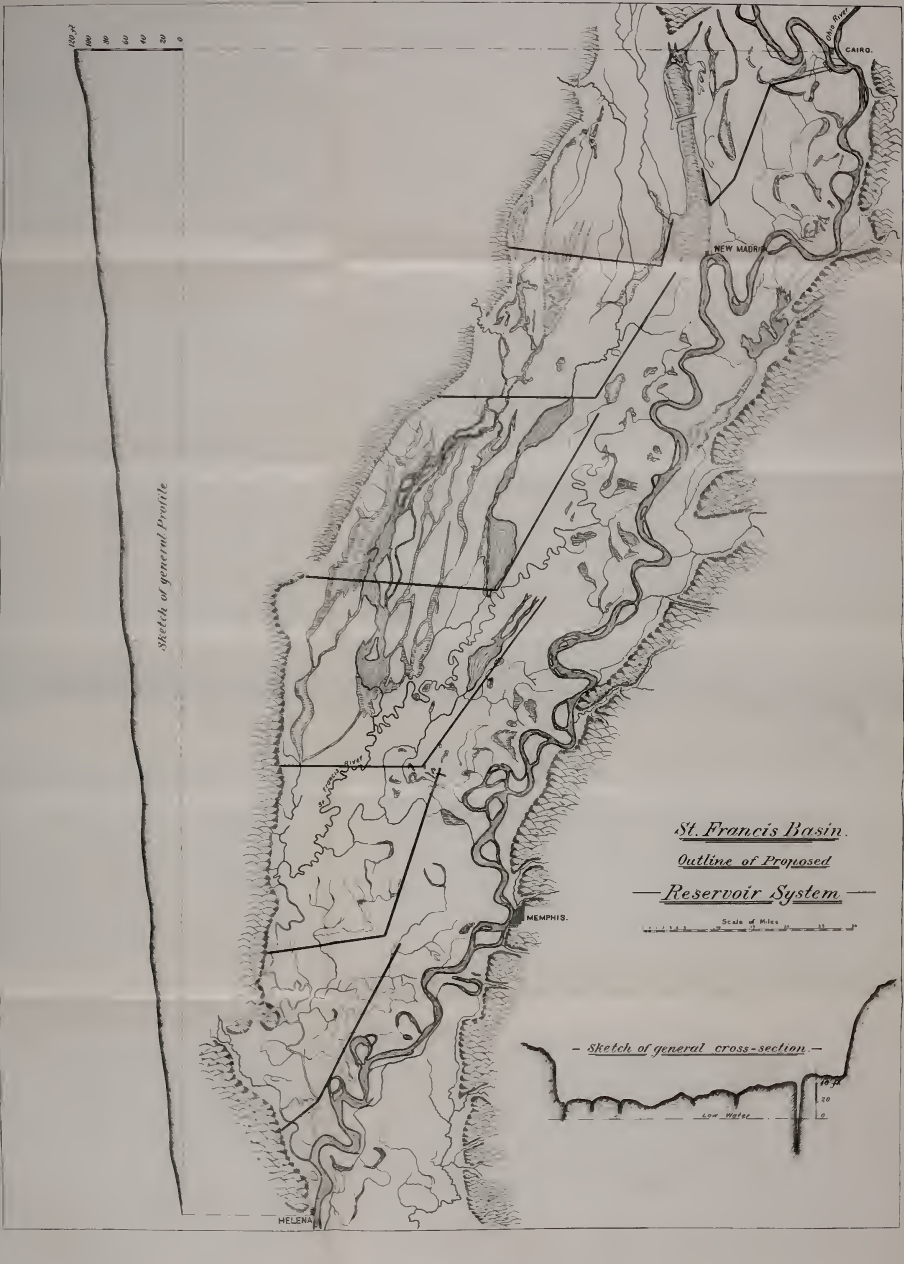
Now, the bed changes corresponding to the case of the Memphis initial flood passed between levees, promise, at least, no general increase in the range between low and high water, and certainly no greater rate of erosion than that of the unleveed river. But this has so far taken a reservoir system, simply to hold back a natural outflow in years of extreme floods, and has not yet considered the case of filling the system annually from the top of all floods and returning the flow to the low water period. And certainly no other case is really to be considered, for, with a reservoir system in the St. Francis basin necessary, the first thing to do is to make the most of it.

As in this the flood excess must be drawn off through artificial outlets, there is no need of flooding the river front with it from Cairo to Memphis; it should be drawn off from as near Cairo as possible. And as the whole question is the capacity of the reservoir system, the extreme flood is in no way limited to the 1882 extreme at Memphis. The matter is to be taken up simply as a problem of reservoir capacity and flood excesses, with the view of seeing what can be reasonably done with it, both for the highest degree of flood and bank protection that can be gotten, and the greatest improvement to the low water navigation.

St. Francis Reservoirs.

Figure IX is a map of the St. Francis basin on which such a system of reservoirs is outlined. Of course, no actual location of such a system can be given without a topographical survey of this basin, which has not yet been made. However, enough of its general form is known to fix the type and set the scale of the reservoirs required. Thus, the basin has a more or less uniform tilt to the south, with a total fall of some 120 feet from Cairo to Helena, as shown in the "Sketch of general profile" given. And, not to exceed the limits of earth embankments, it is seen that a chain of at least some six reservoirs to divide up this fall will be needed here.

Again, the "Sketch of general cross-section" shows the lay of the ground from the river across to the bluffs forming the western boundary of this basin, and in this the general type of the reservoirs is clearly indicated. Each should have a levee on the east, limiting the swamp area to be used for this purpose and holding the water in the back or lower portion of the basin. This longi-


St. Francis Basin.
Outline of Proposed
Reservoir System
Scale of Miles
Cairo.
Ohio River
New Madrid
St. Francis River
Memphis.
Helena
Sketch of general Profile
120 ft
100
80
60
40
20
0
Sketch of general cross-section.
10 ft
20
0
Low Water

tudinal levee begins on grade, taking in the natural drainage from the river to the swamp at its upper extreme, and rises as it goes down with the southern tilt of the basin, till it reaches at its lower extreme the height of the levee that crosses the swamp and closes in the whole reservoir against the high ground on the west.

These lines crossing the swamp would, of course, take advantage of all the high ground that they could follow. They would undoubtedly require heavy work in places, but probably no heavier than some of the front lines on the river already constructed. At the points also selected for the lines of movable dams by which the reservoirs would be filled and emptied, the work would be formed of masonry founded on piles, but in the rest of the line it is thought that earthwork would answer the purpose; or that they would be just what they have been called, cross-levees.

Perhaps, for safety, this should be an especially strong levee, but it does not seem probable that an occasional break here would be any great calamity. It would drain out the reservoir in which it occurred, and would have to be repaired just like a crevasse, but with the provision for rapid filling that the whole system would have, it would seem that it could be drawn off below without endangering the lines following it; while it is only in the event of its occurring just on the top of a great flood that running it out into the Mississippi would make a high water there of any importance.

At the head of this system of reservoirs the outlet for drawing off the flood waters would be located. For this a line of movable dams on the west bank of the Mississippi, just above its junction with the Ohio, would be required. The base of these would be set at about the level of 30 feet on the Cairo gauge, or altogether above the sand movement in the bed of the river; and they should have a range of some 10 or 15 feet in their adjustable crests, fitting them both to fill the reservoirs from the flood periods of any year, or to draw off the extreme excesses of the occasional great floods.

From these dams the outlet would lead back from the river, following some such line as the location shown, first into a double reservoir to the east and the west of the New Madrid high land, and joined by a cut through this high land as indicated. The reservoir on the east would be held between this high land and a line of levees from the outlet down, enclosing such of the swamp lands in the New Madrid basin as might be taken for this purpose. For this reservoir, also, it would be necessary to provide for emptying it back into the Mississippi at low water just above New Madrid.

The one on the west, on the other hand, forms the first in the regular chain of six or more reservoirs extending from Cairo to Helena, as outlined on Figure IX. These all fill and empty in

succession through each other as in the ordinary slack water system of a river. And whatever increase in the navigable depth may be given from Helena down, by emptying the reservoirs on the low waters, it is plain that any navigable depth that may be wanted may be readily carried from Helena up to Cairo through this slack water system. All that is needed is putting in the locks with such dredging, once for all, as the given channels may require.

Without the topography of this basin the capacity of such a reservoir system can, of course, only be roughly estimated. But, covering as it does an area of some 4,000 square miles, or about two-thirds of the flooded lands on the west in this division, it is plain that every foot added to the height of the levees is an immense addition to this capacity. It is thought, therefore, that an average storage depth of some 15 or 16 feet may be taken as a capacity that could be reasonably gotten, without going beyond the character of the work outlined.

Taking this capacity, then, at $4000 \times 15.5 = 62,000$ square mile feet; and this divided by 310 equals 200 days' discharge of a hundred thousand cubic feet a second. With this the reduction of any flood at Cairo, that filling this reservoir system would give, is very easily estimated. It is only necessary to scale the number of days in the successive 100 discharge levels of Figure VIII from the top of the flood down, until the sum reaches this 200 value, to get the level to which this reservoir capacity would cut it off.

This, for the given 1882 flood, is reached at about the level of 42 feet on the Cairo gauge, or, altogether, the reservoir system would have cut this flood down some 10 feet at Cairo. And this is about the least that it would ever do, while in floods of less duration or lower stages, its reduction would be distinctly greater. Such a reservoir system, then, may be safely counted on to cut some 10 feet off the top of the Cairo floods in all cases; while the return of this to the low waters at Helena would about triple the flow there, or add some 15 feet to the extreme low water stages.

In the operation of this system of reservoirs it may be noted that the flood at Cairo is generally in sight far enough ahead to know just about what flood water should be drawn off. In the promise of a great flood the plan would be to regulate the crests of the weirs at the head of the outlet so as to hold down the stage to an estimated maximum. With the given capacity, this maximum for the greatest floods would be about the equivalent of a Cairo stage of 42 feet, while correspondingly lower stages would be taken, as there was less and less promise of a great flood.

The only condition that would present any difficulty would be that in which the promise of a great flood was unusually delayed,

and where in the interests of the low water navigation the reservoirs had been partially filled from earlier rises. In that case, when the promise of a great flood did come, it would be necessary to run out the reservoirs to get ready for it.

In this connection it should be noted that while it takes a rise some four days to pass from Cairo to Helena by the river, the slack water system can take any difference in discharge over this interval instantly. In addition to the week or ten days in which the promise of a great flood was in sight from Cairo, there would also be these four more days in which to run out the reservoirs at Helena. By being careful, then, not to take more water from the earlier periods than might be necessary to insure full reservoirs, in every case certainly nearly, if not all, the full capacity of the system could be counted on to draw off simply the excesses of the great floods.

One point, however, in regard to this reservoir capacity, perhaps, here deserves a further notice. Of course, any reservoir system that is operated with sediment bearing water will in time fill up. But the experience with the settling reservoirs of city water works and the sediment observations taken, make this rate of filling up here fairly well known; and with the one filling a year it would be several hundred years before a serious reduction in the capacity could be looked for from this cause.

This puts the matter at once out of the range of practical questions, but, to those who still like to look so far ahead, it may be interesting to note the probable course of the system in this distant future. The filling up with sediment would, of course, be largely concentrated in the upper part of the system, and by directing it as far as possible into the New Madrid reservoir that might, perhaps, in something over a century, be turned out again as an agricultural district; but a level now composed of the alluvial cream of a continent altogether above the plane of high water instead of below it. One by one, in the same way, the reservoirs forming the chain from Cairo down would follow this course; preserving, however, the channels through them for the slack water system of navigation and for filling below.

The final outcome in something over a thousand years would be a wholly filled up swamp with a double channel for the Mississippi; the front carrying the ordinary river, the back one used as a slack water system and discharging the flood excess at Helena from level to level with its form of immediate transmission. But how far the developments of that day might make a further extension of this down desirable, must be left to the man of that distant future to determine.

Returning, however, to present conditions, it is plain that with such a reservoir system so operated, the flood regimen would be

quite different from that of the case first considered, where only the natural outflow into this basin was to be held back. True, at Memphis the extreme flood would not be greatly changed; in the place of the 1,200 discharge there this reservoir capacity would cut the top of the flood down to about 1,100 or to a 32 foot stage on that gauge; but the ordinary flood would be much more markedly reduced.

With no change, then, in the low water flow except the small contribution from the New Madrid reservoir, from Cairo to Helena, the river would be a case of about the present low water regimen with uniform but markedly reduced floods imposed upon it. And changes of bed might be expected to follow this change in the flood regimen; but there is no reasonable doubt that they would be altogether in the direction of a better river.

But at Helena the wholly new regimen begins. With some 10 feet cut off the top of all floods there, and this hundred thousand cubic feet a second for two hundred days to put back on the short low water period of this river, the range from high to low water even in extreme floods would be little more than 25 feet, while its ordinary rise and fall would be near 15—in contrast with the condition of a complete levee restraint with its ordinary range sometimes over 40 feet, and an extreme range of more than 50.

This reservoir system simply cuts the extreme flood off about to the bank level as far down as the White and Arkansas rivers, where the contributions from these tributaries may be expected to again raise the high water line; and a moderate levee system is required for a complete flood protection from there to the gulf. However, the levee system already completed here, is certainly enough for any possible contingency, while there are possible contingencies in the combinations of these lower floods with a complete restraint from above, that no levee system yet considered would begin to stand against.

But in the same connection the difficulty of keeping up a levee system on the caving banks of this river is also to be considered. What the rate of erosion would be in the greatly reduced range of stage effected by the reservoirs is, of course, not known; but the problem of bank protection is something like that of the retaining wall. It may be cheap and easy at ten to twenty feet, and extremely difficult and costly at fifty; and it is not unreasonable to expect that the reservoir system would reduce this difficulty to a small fraction of its present proportions, even if it did not entirely remove it.

With the banks also reasonably stable, the one great difficulty in the way of channel works for improving the low water navigation would be removed. For otherwise, to put such works in the river,

with this lateral movement of the river going on, is to put them where in a few years at best they would be useless, if indeed, they do not become absolute obstructions. But with the greatly reduced erosion on the one hand and bar building on the other that this new regimen promises, and some 15 feet added to the stages of the low water flow, a navigation altogether beyond the range of anything that has yet been considered possible is already secured without any channel works whatever.

So far as navigation is concerned, this reservoir control simply opens a highway for ocean commerce right into the heart of this continent. But what such a thing may mean to a country is probably the last thing that the country begins to realize. Unlike the flood and the bank protection that serve immediate interests, with like aids to existing navigation, this is an interest which does not yet exist; and the great body of the people that are to be affected by it are slow to realize the possibilities that lie in such a creation, even where they have a parallel of it right under their eyes.

Were the lake control of the St. Lawrence water-shed eliminated, a canoe could hardly have reached Duluth in the natural river; and that city would have been impossible, with Chicago probably never heard of, and Cleveland and Buffalo but way stations on single track railroads, and the grain of the Northwest would have been locked in, and the ores of Superior, that are making this nation the ironmaster of the world, hopelessly sealed in an utterly inaccessible interior for centuries.

These are matters that are the province of the statesman to foresee, and governments to create; and it is simply the opening of such a line of commerce from the gulf up, that is here proposed; and this also made on exactly the same principles. Of course no such great areas are to be sacrificed to it—the reservoirs are to cover less than half the area of Lake Erie—but they have their power of control multiplied by ten in the 15 or more feet annual oscillation that is given them to replace the foot or so of like oscillation in the lake levels.

That this natural system of the North would be joined to the artificial one of the South may be counted on, and a line of internal seaboard right through the center of this country would then mark the earlier decades of the new century—a creation whose far-reaching utility is quite a different thing from fostering waterways, with or without traffic upon them, for the avowed purpose of controlling freight rates. It is such commercial arteries that make a cheap distribution possible on the network of railroads that spring from it, and at the same time make their business pay.

Comparative Costs and Estimates.

Before considering estimates of the cost of such a reservoir system in the St. Francis basin, a brief outline of the estimates of alternative projects, reached after some twenty years' work on them, may be first taken for comparison. For of course, doing anything with a river over a thousand miles long and a mile wide, is a big undertaking.

On the levee system for flood protection the states have spent in round numbers some $35,000,000, and the general government $15,000,000, while it is estimated that an expenditure of $20,000,000 more will be required to finish the work, putting the whole system in shape for a complete flood restraint. After this, it is estimated that to keep the system up will cost in renewals and repairs some $2,000,000 annually.

In the matter of a general bank protection on this river the net result of all expenditure has been simply to bring the river engineers to look upon it as practically a hopeless undertaking. Repeated failures, year by year, have shown the need of heavier work over wider areas to hold these banks against erosion; and it was not until a protection that cost some $30 per running foot was reached that even a reasonable degree of success was met with. With this, a system of bank protection has been variously estimated at from $60,000,000 or $70,000,000 up to $120,000,000, with from 5 to 10 per cent annual repairs.

These estimates differ mainly in the number of miles of bank to be covered that such a system would require, and, of course, where there is such a wide margin of uncertainty the thing can hardly be called an estimate. But as both of the extremes were alike taken simply as the ground for finally giving up a general system of bank protection on this river, it is probable that no experienced engineer, who had in view actually doing the work for the money, would take the costs at less than 500 miles of bank at $30 per foot, or, say, $80,000,000 with $5,000,000 annually for renewals and repairs.

However, even with a general bank protection given up, there is a continued call for large expenditures in this line, protecting concentrated values on town fronts, and special bends that threaten a a cut off. But how far the river, left free to change its course at will in the reaches above, will come in time to flank these local works and cut them all out is still a problem.

With the system of bank protection given up, of course channel work for the improvement of the low water navigation goes with it. For, as before noted, to put such works in the river without at the same time holding the river in its place, is to put them where they can do no permanent good, and may come to be very much in the

way, if they are not cut out by the river in its channel changes. The question of whether any material improvement to navigation in this river could be gotten at reasonable cost by works of this character has, therefore, as yet hardly been touched; but as it is barred at its beginning by the excessive cost of bank protection, it is not much of a practical question anyway.

But government works on navigable rivers can hardly ignore the interests of navigation altogether, and to meet the case thus presented a very extensive system of dredging low water channels has been inaugurated. The task is admittedly an endless one, for each high water obliterates the work of the low water season preceding it. But as a development in hydraulic dredging, and for the capacity attained of moving large quantities of this bar material in short times, it is certainly a great piece of engineering.

But even with the fleet of powerful dredges now engaged in this work, the actual improvement to the low water navigation that can be gotten is necessarily quite limited. With the bars often several miles in length, cutting low water channels through all of them, over the 600 miles of river between Cairo and Vicksburg in this short low water season, is not a task in which any great addition to the depth can be attempted, and perhaps an average of some two feet increase may be taken as its limit. For this an annual expenditure of $200,000 to $300,000 is estimated, including repair of plant and percentage for its renewal.

Now, in contrast with the estimates above, the cost of the St. Francis reservoir system is to be considered. And while, of course, such costs in advance of an actual survey and location of the work are necessarily but rough approximations, they are, nevertheless, estimates of plain construction outside of the river, and may be counted on with much more confidence than any estimates which have its destructive forces to deal with.

Each of these reservoirs may be then taken as formed of 25 miles of cross levee at $90,000 per mile, and 25 miles of longitudinal levee at $30,000, or an average of $3,000,000 for the earthwork in each of them. This $90,000 per mile will build at average prices a levee altogether heavier than the standard section, safe for some 25 feet of water against it; while the longitudinal levee is proportioned to run from grade up to it. This estimate, however, takes it simply as team work, while it seems probable that it could be built with hydraulic dredges, in which case it would be at least a third cheaper. In addition, the filling and emptying systems would take an average of some 2,000 feet of movable dams at $200 per foot, and 2,000 feet of fixed weirs with flash boards at $150 per foot, or altogether $750,000 to the reservoir, making the total esti mate for the six reservoirs $22,500,000.

For the flood water outlet, the weirs at its head should have some 6,000 feet of movable dams at $300 per foot, or $1,800,000, while the channel leading back from it would require about 100,000 square feet in the area of its cross section. This, as soon as the grade permitted, should be taken with about one-quarter of its section in cut and three-quarters in embankment, and would be hydraulic dredge work altogether. Probably from $3,000,000 to $4,000,000 would be a full allowance for it, but without a location and levels very little in the way of an estimate can be made of it.

In the matter of damages the area to be flooded is now some two-thirds land and one-third water, and taking the 4,000 square miles altogether at a dollar an acre, which was formerly a good price for swamp land here, makes it $2,560,000. Or, again, the testimony before the sub-Senate committee in 1898* put the estimated value of all the land in this basin at $8,600,000, and probably three-quarters of that, at least, lay in the high ground next the river that is left outside of this reservoir system. With a promised protection of this area, then, once for all stopped, it would seem that some $3,000,000 was a fair estimate of the actual land values sacrificed in this work.

However, it should be distinctly understood that every dollar the government has spent and is spending on the front levee line in this promised protection is probably adding ten dollars to this item in the cost of a reservoir system here. And what, perhaps, is even more questionable, in the place of taking the land as it is, it is leaving it to be sold for farms by speculative interests at large profits, to be taken from its final owners when the educational flood at last comes that makes the necessity of this reservoir system fatally apparent.

A summing up now, of these items, for the total cost of this reservoir system gives:

Six reservoirs, complete, ...	$22,500,000
Outlet, weirs and excavations, say . .	5,500,000
Land damages, say	4,000,000
Total, . .	$32,000,000

This, however, has not yet considered the development of the system of slack water navigation through the reservoirs from Cairo to Helena. With this a link in a great commercial highway, the locks, of course, should be of ship canal dimensions and would be large works, costing some $2,000,000 each, or $12,000,000 for the six of them. These, of course, should go in with the construction

*55th Congress, 3d session, Senate Report No. 1433, page 436.

of the reservoirs, but dredging the channels here could be done as it was needed. And, certainly, in the place of cutting low water channels that fill up each season, the fleet of government dredges could be profitably set to cutting a channel, once for all, here that would not fill up in a century.

For a general summary, then, of all these estimates, existing projects call for:

Flood Protection—$50,000,000 expended and $20,000,000 more estimated to complete it, with $2,000,000 yearly for maintenance.

Bank Protection—$80,000,000 estimated to complete it, with $5,000,000 yearly for maintenance. This, however, now given up.

Navigation—Permanent improvement; given up with bank protection, but $250,000 to be spent yearly in dredging to give some two feet greater low water depths.

St. Francis Reservoir System—Cost, $32,000,000, and gives:

Flood Protection: Complete; no cost of maintenance; saves from 1,000 to 2,000 square miles of cultivated land otherwise drowned out, and greatly reduces the flood risk to the whole valley

Bank Protection: Little, if any, then needed; probably a fraction of the cost of maintenance in the other case would in this case fix the whole river permanently.

Navigation: From Helena down, at least doubles the extreme limit of navigable depths aimed at in existing projects if, indeed, it does not more nearly triple them; and opens an extension of a like navigation from Helena to Cairo at present cost of $12,000,000, with dredging to follow as needed.

Finally, it may be noted that in the last 20 years the government has spent on this river some $40,000,000, or just about the cost of the St. Francis reservoir system with slack water navigation to Cairo. That it has spent the most of this to pay for experience is now generally admitted; and it may also be admitted that, perhaps, it could not have gotten this experience any cheaper. But, in any event, if the matter was worth beginning it is certainly now worth finishing with such a waterway in sight, carrying as it does this high degree of flood and bank protection with it. The final question then is simply: Having paid $40,000,000 here for experience, does the country now propose to profit by it?

WRITTEN DISCUSSION.

[The following written discussion by Mr. L. E. Cooley, on Mr. Seddon's paper on Reservoirs and the Control of the Lower Mississippi, has special reference to the relation of the project to the lakes and gulf waterway.]

Mr. L. E. Cooley—The importance of Mr. Seddon's paper cannot be overestimated. It is the summary of twenty years of experience, the residual analysis of the enormous mass of data gathered in that period and the epitome of forty millions of expenditure, and it takes its place in the array of results from less ample fields.

The possibilities were boundless and the lessons to be learned justified the cost. Though doomed to ultimate disappointment, the optimist was best adapted to push theories to the limit. Out of it all should come knowledge, a wise program and encouragement. The professional world is entitled to an exhaustive monograph which shall set forth the data and expose their bearing. Such presentations by master minds have made epochs in scientific annals and turned the thought of the world. But in the changing personnel of military policy and the expediency so often lurking in civilian service, is not this hope to be indefinitely deferred?

For three-fourths of a generation has Mr. Seddon devoted himself to physical research of the Mississippi river and its tributaries. He is the saving remnant from among a number of early and enthusiastic workers. That he should give his time to exploiting his researches in this and other papers, is a matter for congratulation.

It is refreshing to return with a broader view to first principles, after the exhaustive threading of by-paths through the underbrush of detail which usually close near the starting point. The river is the physical expressions of the forces that made it, the climatology, topography and geology of its basin, and its features are accidental only in a narrow and restricted sense. Any material change of a permanent character must, therefore, be produced through a change in the determining conditions.

The immediately related factors are the declivity, the volume and the variations therein, and these express themselves in what may be called the physiognomy of the stream bed.

An excess of energy from declivity produces a dissipated stream bed. To artificially constrain this within narrow and uniform limits eventually results in a lower declivity; but the period of transition is long, the works must follow down to lower planes and the improvement in navigable depth is meantime uncertain. These relations have been understood (academically) from the outset. An

early advocate talked of setting Cairo on a hill. Abroad, works of rectification have been in progress for generations, partially to fix river banks in the interest of marginal lands, resulting in deeper pools with little change in bar depth and a re-arrangement of slopes which, in their final adjustment, involve a long period of time. This has led to the breaking up of pools by the construction of artificial bars, called ground sills, so as to better distribute the minimum depth and proportion the resistance to the declivity. It has also led to a recognition of the propriety of taking out a part of the fall by means of dams and regulation on the lowered declivity.

In the case of the Lower Mississippi, it was contended that there are certain anomalies in the low water profile that could be corrected without disturbing the regimen as a whole, as in the New Madrid, the Osceola and the Lake Providence reaches. The results of the works at these localities may not be conclusive, but are so accepted by many, though good water seems to have prevailed through the Osceola reach for several years. The cost, however, has been very great.

In the interest of navigation, solely, the policy has been experimentally developed of maintaining a minimum depth of nine to ten feet across the bars by means of hydraulic dredging. These cuts are made on the falling stage and are found to persist through the low water season when judiciously located, but are obliterated by the following high water. The cost is estimated at $200,000 to $300,000 per annum, which certainly is a small sum in proportion to the cost of maintaining the roadbed of a railway for the same distance and for an equivalent traffic.

In former times and in extreme low water years forty-three places below Cairo were liable to depths of less than ten feet, twenty of which might have less than seven feet and thirteen of these five feet or less. Above Cairo a number of places were liable to depths of four feet or less, though a material improvement seems to have been made by regulation below St. Louis, with a concentration of slope in the reach above the city.

There seems to be a reasonable assurance that, by means of hydraulic dredges, the river can be maintained at a limiting depth of nine to ten feet below St. Louis at a cost amply justified; and this fact is very important as maintaining a live interest in the stream until such time as a broad public policy will deal with conditions that shall work a permanent change for the better.

If a material change in the relation of bed to declivity in this great river is beyond the limit of practical achievement by regulating works, there is yet to be considered a change in conditions as to variation in volume. The stability of regimen due to uniformity

in flow needs only to be stated. Everyone recognizes the equalizing effects of lakes, swamps and woodlands; and the remedial effect of reservoirs early suggested itself.

The river bed itself is a great reservoir, which modifies a flood in its course, and this action is supplemented by high stage overflow, the effect of which is to prolong the floods near the bank-full limit. If these high stages were long continued, which would be an approach to uniformity, no doubt the bed would conform with a sufficient capacity; but they are too short in duration for a full response, and the necessary result is overflow in rivers varying widely in volume. The bank full limit is the practical measure of the working forces involved. To reduce the maximum and increase the minimum, though the total energy remain, is to apply the forces between narrower extremes and inaugurate a radical change in conditions for the better.

The natural overflow reservoirs of the Lower Mississippi return their volume to the stream often at inopportune times, and to the detriment of the reaches directly affected; nevertheless, the aggregate result through the ages has been a substantial regulation of volume below Red River and a prism of most economical form on a moderate declivity. Since man entered on the alluvial lands, over 160 miles, or more than 20 per cent, of the length between Red River and Cairo has been lost by cut-offs. Nature's efforts at stability under overflow conditions, by reducing the energy through distribution, have been defeated. All the energy due to this shortening, increased by efforts at flood concentration, has been thrown into dissipation of stream bed, with perhaps an eventual recovery of length at tremendous sacrifice of land for a new location in part.

The natural wealth in these alluvial lands is so great that every one concedes their reclamation as a condition precedent, whatever the results to the regimen of the river. The levee was the obvious individual recourse, gradually expanding into collective effort, then developing state control and enlisting national patronage, and now reaching the final stage of national responsibility. This is but a natural evolution by reason of the wide forces involved, and it would be strange if these great purposes had not unconsciously fathered theories of river improvement more or less cogent.

The levee theory proceeded on the assumption that by confining the entire volume to the channel, the stream bed would thereby be deepened; but the additional energy refuses to discriminate in favor of the bed as against the banks. This added energy is largely a force of dissipation, already in excess under overflow conditions. Efforts so far developed show the necessity of greatly increased levee height and strength for the full control of extreme floods; but whether there will be an eventual lowering of the

flow line if the system were fully developed, and whether in such event it can meantime be maintained, are matters of hope rather than demonstration. The disastrous experience of the centuries with the great rivers of China may not be in point, for no adequate research into conditions from the modern standpoint has been made.

In any event the tendencies are adverse, especially from the standpoint of navigation. A broader and more variable bed, wilder wandering and more eager bank erosion and greater discrepancy between bar and pool depths, are likely to attend on the accentuation of extremes.

The levee policy is the converse of the project of Mr. Seddon. Rather than increase the maximum volume flowing in the river, he proposes to greatly reduce the same by drawing off and storing, once for all, the excess of volume above bank height that is now drawn off and returned to the river repeatedly between Cairo and Red River. This is to be done near Cairo, and some four thousand square miles in the St. Francis basin are to be appropriated for a series of reservoirs.

These reservoirs are to have such capacity that the flow in the main river may be practically restricted to the bank-full stage, so that no further development of the levee system will be required. The volume drawn off at high water is to be restored at Helena on the low water stages and is calculated to produce a navigable depth below of not less than twenty feet, which is to be carried up to Cairo by slackwater through the series of reservoirs. It is estimated that the range in stage below Helena will be reduced from about fifty feet under full levee conditions to some twenty-five feet, thus greatly reducing the problem of bank conservation. In non-overflow years it is proposed to draw from high water and fill the reservoirs in the interest of low water navigation.

The marginal lands that will thus be available are considered as an offset to part of the area that will be appropriated, and much of the remainder is of little value or irreclaimable. The questions of sedimentation and control are fully set forth in the paper under discussion.

The carrying out of such a project would reduce the present ratio of volume between flood and low water from 12 to 15, to something like 4 to 5. So great a step toward uniformity promises radical changes in regimen aside from the mere taking off of a high stage and the adding to a low stage. The narrower range in volume should assimilate the high and low water regimens, now radically divergent; the bed conformation should change in favor of a

greater depth on bar in respect to pool and tend toward a lower declivity, and the smaller range in energy and in stage should greatly lessen bank action.

The project of Mr. Seddon promises so much, and so fully recognizes the primary dynamic conditions, that it should receive the most serious attention and exhaustive investigation as to the actual possibilities of the site and the treatment proposed.

So much for the local reservoir treatment of the Lower Mississippi.

Some consideration of broad questions of public policy is useful as a backsight for matters within the range of early achievement.

Civilization in organized communities dawned in the use of waters on arid lands. From immemorial time, actual and beneficial use has determined proprietorship. The doctrine, no doubt, developed in those necessities of the state which required the fullest development of limited resources, and is not unlike that of the school of economics that would vest the control of land only in the actual user.

The same doctrine obtains in humid regions, so far as demanded by public necessity, as in the appropriation of water for domestic and industrial uses, for the supply of cities, for purposes of navigation and, in a restricted sense, for water power, subject only to the limitation that riparian enjoyment shall not be needlessly and willfully impaired. The extent and nature of appropriation is a matter of public policy.

The conservation of water for beneficial use has been long advocated by the writer, not only in the great lakes and other natural reservoirs, but in artificial reservoirs wherever the situation invites. These views have been strengthened by recent studies in the arid regions, and now a far reaching public policy seems to justify the conservation of waters to the fullest practicable extent. The writer, therefore, demurs to that general inference of the paper under discussion, which seems to deprecate the control of head waters, and assumes that it was only designed to show that the effect would be relatively small and indirect for the specific purpose under consideration.

It may be admitted that extreme head waters often, perhaps generally, contribute little to the maximum flood in the outlet of the basin, their function being rather to prolong the stage, though much depends on the relation of the basin to storm tracks and other facts of climatology. By parity of reasoning, the control of such waters would not greatly affect overflow at remote localities. On the other hand, the contribution to low water is an actual and

potent factor to the extent of its volume from the point of origin to the sea. Again, conservation carried to attainable limits in a large basin would profoundly affect both high and low water flow throughout both the tributaries and the main outlet.

The exception is in the arid region where public necessity will eventually consume all water. There are some 800,000 square miles in the United States without sufficient moisture for profitable tillage, and if all the water be economically utilized not over 12 to 15 per cent of this area can be reclaimed for agriculture. Such development demands the storage of all surplus waters to the time of most beneficial use, and such policy will prevail so far as conditions admit. Rivers originating in the arid regions may therefore be dismissed from this consideration, except as to their humid sections.

It is possible to store in the upper lakes, without undue fluctuations, the variation in volume, or the surplus above the minimum flow at Niagara, and divert, perhaps, 100,000 cubic feet per second southward. With such added volume a waterway could be produced from the lakes to the Gulf of Mexico that would work a revolution in transportation conditions on this continent, and power would be created for industrial development in the very bread basket of the continent. As the minimum substantially measures the utility of the eastward flow, the interests vested in the natural conditions in Lake Ontario and the St. Lawrence would not be materially impaired, and corrective works and a radical improvement for navigation would be facilitated. The possibilities are so well within the resources that might be applied that to become practicable requires only public conviction.

It is possible to divert to the lakes many headwaters of the Upper Mississippi and the Ohio, probably tens of thousands of miles, and divert an equalized flow through a new outlet without greatly disturbing the flow in the natural outlet. Could such diversions be as great as 100,000 miles, they might reduce extreme flood volumes by 10 per cent at Cairo, provided these diversions were so distributed as to admit the theory of normal basin ratios. The effect would be larger up stream, and, locally, floods would be quite suppressed. Such diversions could well form part of a general policy of conservation.

Suppose it were practicable to devote the equivalent of one section in each township to reservoir use, and store therein a depth of twelve feet. The average run-off may be taken at one foot ; it will be less for the Upper Mississippi and greater for the eastern Ohio. This reservoir would store one-third the total run-off for a year, but it is assumed that local utility demands a continuous and

uniform flow. Under average conditions of precipitation in humid regions, a cistern of a capacity of about one-third the total rainfall on a roof is sufficient to distribute the same in a uniform flow. On land a fraction only of the precipitation runs off; it accumulates in snow, and is consumed at other seasons by vegetation, by evaporation and by percolation and absorbed by an arid soil, and the seasons vary greatly. So it will be conservative to assume half the average run-off as under control.

The effect of such a system throughout a basin would be to quite do away with some, and greatly reduce all, floods, and there would be established a minimum flow of not less than half a foot for each square mile of watershed, substantially in addition to the natural flow generally existing. These conditions would obtain not only in the main outlet, but in every tributary and in every creek leading to a reservoir.

The possibilities of navigable development become unlimited, and water power becomes everywhere available. Value is everywhere attached to lakes and running streams for general utility and as objects of beauty and pleasure. Sections of China by fish culture produce more food than from equal areas of land, and even the Illinois river for several years has produced a fish crop that has sold for more per acre than have the farm products of Illinois. The compensations for the land used are many.

The opportunities for storing water are endless when enlightened public policy shall make the need apparent, and the benefits to be derived are only less than in arid regions. No other development is conceivable that is charged with larger possibilities for the common welfare.

From Lake Michigan at Chicago to the mouth of the Ohio river at Cairo is 550 miles in round numbers, and it remains to discuss how twenty feet may be carried to that point to meet the project of Mr. Seddon and make a through route of that navigable depth from the great lakes to the Gulf of Mexico.

The "Chicago Divide" is in reality a deep cut valley across the rim-ridge of the lake basin, and is known geologically as the Chicago Outlet, which drained Lake Chicago southward in quite recent geologic history. The rock floor is but seven feet above low water of the present lake, though alluvial deposits are four feet higher, and only thirty feet above the Niagara outlet at Horse-shoe reef, opposite Buffalo. Prof. G. K. Gilbert, of the U. S. Geological Survey, has estimated that changes now going on will fully restore the ancient outlet in about 2,500 years.

For present purposes the Chicago Divide may be taken as that portion of the outlet from Lake Michigan to Lake Joliet, over which

work has been done by the Chicago Sanitary District, some five miles by the Chicago river, twenty-eight miles by the sanitary and ship canal and some eight miles down the steep slope from Lockport through Joliet, in all forty-one miles to the pool at an elevation of 76 feet below low water of Lake Michigan.

A well defined outlet valley and a developed stream bed extends from Lake Joliet to the Mississippi. The upper portion extends 54 miles to the head of the pool near Utica with a descent of 66 feet, reaching a level 142 feet below Lake Michigan. The river is for the most part 500 to 700 feet wide and descends by pools and rapids according to the resisting strata.

The lower Illinois is entirely alluvial and extends from Utica 227 miles to the Mississippi near Grafton with a declivity from pool level to normal low water at the mouth of 32 feet, or only 28 feet in the natural river. The values reported have varied two or three feet with the low water stage taken. The bed is generally from 600 to 900 feet wide, and some 700 square miles of bottoms are subject to overflow which is complicated by backwater from the Mississippi, the extreme high water of which is on a level with natural low water 30 miles below Utica. This extraordinarily low grade is unique among American rivers and is significant of the great volume of the ancient outlet, and the remnants of the old bed still exist in the deeps above Havana and the broad expanse above Peoria which have been much encroached upon in the historic period.

From the mouth of the Illinois to the Merchants bridge at St. Louis is 39 miles, with a descent of 21 feet, two-thirds of which is within the lower half of the distance. There seems to be a concentration of slope above St. Louis, due probably to the narrowing of the river for several miles opposite the city and the improvements below.

The Middle Mississippi extends from the mouth of the Missouri, 14 miles above the Merchants bridge, to Cairo. From the Merchants bridge to a point where the bluffs disappear between Thebes and Commerce and at the virtual head of the alluvial valley of the lower river, is a distance of 150 miles with a declivity of 78 feet; thence to Cairo point is a further distance of 39 miles with some 30 feet of fall. Low water at Cairo is approximately 303 feet below low water of Lake Michigan and 275.6 feet above mean tide of the Gulf of Mexico. The distance to the gulf is some 1,070 miles, and about 300 miles less to Red river.

The old Illinois and Michigan canal extends from the Chicago river 96 miles to La Salle, and the summit was cut down to lake level so as to draw its water supply from Lake Michigan. Locks and dams were constructed by the State in the lower Illinois at

Henry and Copperas creek, and by the United States at La Grange and Kampsville, and these were designed for seven feet, but the pools have not been dredged. A depth of six feet was projected in the Mississippi at low water above St. Louis and eight feet below. Some dyke work has been done near Alton, St. Louis harbor improved, and regulation works more or less advanced for fifty miles below.

The accompanying profile from Lake Michigan to Cairo exhibits the elements of distance, grade and depth.

In 1889, the state of Illinois provided for a canal to carry 10,000 cubic feet per second across the Chicago divide, from Lake Michigan to the valley of the Illinois. The immediate cause of action was the sanitary necessities of the city of Chicago, and authority was granted after ample investigation had shown that the purpose could be served without detriment to any interest and in harmony with a sound and far-reaching public policy.

In consideration of the privileges to be enjoyed by the city of Chicago, under proper safeguards against abuse, the state of Illinois required that the canal should be built under a waterway specification, and that it should be a navigable stream in law and in fact. Appreciating that the old type of canal had become obsolete, and that the works projected and then partly executed for the lower Illinois were inadequate to future requirements, the public policy of the State was declared to be to procure all the depth practicable by the aid of a water supply from Lake Michigan, and that the navigable depth should not be less than fourteen feet; and the removal of the State dams was ordered, and the United States was requested to stop the work on existing plans and change to an open channel deepened by dredging. The State and its citizens have repeated these declarations on every suitable occasion, and it is not creditable to professional sense that they should have remained so long unheeded.

The reasons for this change had been well considered. A larger depth was not only possible but was essential to the maintenance of a channel over the low declivity of the Illinois. Banks were low, overflow was wide and inhabitation was fast bringing the spoils of the land ; natural forces of deterioration were unhappily accentuated by the obstructing dams. What was then obvious to the discerning has since been demonstrated by two examinations and is generally accepted by the well informed. The remedy is a strong flow in a deeper channel, to be secured by removing dams, by dredging and by a water supply. This accorded with every riparian and

sanitary interest, so every consideration crystallized in the one policy.

The agency created is the Sanitary District of Chicago, which has so far carried out the works authorized as to open the main channel for a part of the water contemplated by law. This channel carries some 24 feet below low lake level, and is 160 feet wide for nearly fifteen miles through rock, and 202 feet wide on bottom, and 300 feet at the water line, so far as completed in earth cutting, toward Lake Michigan. Some thirty-five million dollars have been already expended and the eventual completion will probably involve fifty millions.

Over the eight miles down the steep slope from the end of the canal at Lockport and through Joliet to Lake Joliet no cheap solution offers, and the boldest and most radical plan promises the best results, as measured by cost. The studies have proceeded on the theory of extending full canal depths to Lake Joliet in a prism ample for all floods so as not to disturb commercial use, the locks to be adequate for a fleet of six barges, each with a dead freight capacity of 2,000 tons, rafted with a towboat for river towing. This portion of the work has been estimated at eight million dollars, over a length of eight miles. The doing of this portion by means of prison labor, under the auspices of the State, has been discussed. A bill looking to that end passed the General Assembly of Illinois in 1895, but failed to receive executive approval.

From Lake Joliet to Utica is a simple slackwater proposition of 54 miles and a descent of 66 feet, which can be covered in three levels. The natural flood velocity over the declivities is considerable, and a liberal prism is required to reduce the same to proper limits, involving heavy work at localities. A study and estimate have been made for 16 feet, with miter sills at 20 feet, so as to permit future deepening; also, with the levels so arranged as to permit the flow line to be raised four feet, if ever demanded. The estimate is ten million dollars.

From Utica to the Mississippi is a plain proposition for cheap hydraulic dredging for the most part, for a channel of a bottom width of 300 feet and carrying 14 feet of water. Something less than seventy million yards are involved,with no allowance for assistance by the stream, and back channels, sloughs, marshes and adjacent banks furnish convenient places for deposit in most localities. The estimate has been taken at seven million dollars. A special dredging fleet developing the work progressively through a series of years would probably produce a more liberal channel for the estimate and so place the material as to assist in the reclamation of the bottoms.

The total is twenty-five million dollars from the end of the sani-

tary and ship canal at Lockport to the Mississippi near Grafton, a distance of 289 miles. This is only half of the liability devolved upon the Sanitary District of Chicago. Over the first eight miles the works must be completed as a whole at the outset. The remainder of the route only requires three locks and dams to be built to their final capacity at the outset, while the prism of the river may be progressively developed.

No detailed studies have been made over the 39 miles from the mouth of the Illinois to the Merchants bridge at St. Louis. The slope of the Mississippi is quite easy, about seven feet for the first twenty miles, while it is some fourteen feet over the following nineteen miles and complicated by the entrance of the Missouri. A dam at the end of the twenty miles and below Alton, raising low water perhaps ten feet, would conform to the easy slopes of the Illinois and make the extension of deep water to this point comparatively easy. Regulation works may lower the low water plane still further at St. Louis and such a dam will furnish a point of rest up stream. If the Missouri should unduly complicate the extension of works of regulation to the dam, as a last resort, it would still be feasible to carry deep water to St. Louis harbor by a short canal and by developing channels behind Chouteau and Cabaret islands. No estimate has been made of this section and other solutions may offer, but much may be left to the citizen of St. Louis when he realizes the probability of deep water within a few miles of his door.

A project of not less than fourteen feet between Chicago and St. Louis would be justified if no Mississippi river existed. These are the dominant foci of the great interior, and at and between them swings the east and west movement of a continent. The Mississippi, with fifteen thousand miles of navigable tributaries, subject to development with the growing resources of the great valley, is only a further argument in justification. But the assumption that the Mississippi is not now available for a through navigation of fourteen feet, is not warranted.

A study of the stages of water will show that this depth can be carried through for five to seven months of the average year, and the experience in old steamboat days, with such craft as the Grand Republic and Jim Howard, justifies this inference.* Barges that are stanch enough to traverse the great lakes and the Gulf of Mexico and Carribbean sea, will find ample reason for using this period which would not obtain in a purely local trade. An assumed minimum of nine to ten feet is promised, which would prolong this

* "The stage from Cairo to the Gulf for two thirds of each year gives a navigable depth of over twelve feet."—Statement by John A. Ockerson, Member Mississippi River Commission.

period to seven to nine months, or to that of the eastward route, owing to closing by ice, and there would still be an available navigation for the remainder of the year. The upper Illinois may be closed by ice for sixty to seventy days, and in many years not at all. With the aid of ice boats, interruptions would be rare and of short duration.

To obtain twenty feet through the lower Illinois is simply a matter of water supply and dredging, and the greater depth and volume are simply further elements of insurance against deterioration. A large volume is as desirable on the low declivity of this stream as is low declivity for the large volume of the Mississippi. From Utica to Alton dam a channel of increased width would probably demand the removal of additional material of double the amount required for a channel of fourteen feet, and necessitate a water supply of 25,000 to 30,000 feet per second.

The structures have already been projected for the capacity, and the additional work for the enlarged prism between Utica and Lake Joliet would be a fraction of the total estimate for fourteen feet. The works between Lake Joliet and Lockport are already presumed to be adequate, and little additional would be required; but this situation may be improved by diverting the headwaters of the Desplaines to Lake Michigan.

Had the additional volume been provided for in the original construction of the Chicago canal it would have added little more than the additional excavation, or less than half the total liability of the Sanitary District of Chicago. To provide the additional volume will probably cost 60 or 70 per cent of that total.

The additional work from the Alton dam to St. Louis is simply a question of prism, not involving a large additional cost in the project for a separate channel over a part of the distance. The confluence of the Illinois, Upper Mississippi and Missouri all occur opposite an extensive bottom in a distance of twenty-five miles, and there are possibilities therein of changes in course, and a full study may develop a superior project.

The probable estimates are as follows: For a total of some eighty million dollars it is practicable to secure a navigable depth of fourteen feet between Lake Michigan and St. Louis, with a depth of twenty-four feet over the first forty-one miles, and this depth can be carried to Utica, ninety-five miles from Lake Michigan, at a moderate additional cost. Of this total the Sanitary District of Chicago is liable for fifty millions, and the State may be persuaded to donate prison labor for eight millions more. The remainder, twenty-two millions, is for a progressive development, half of which must be expended before a navigable route can be opened.

For an additional sum of 70 to 80 per cent, or about sixty million dollars, it is practicable to increase the navigable depth to twenty feet. After half the sum has been applied, the remainder will be a progressive development.

The project outlined by Mr. Seddon would logically carry the slack-water canal of his reservoir system through bottoms that come to the Mississippi in the bluff gap between Cape Girardeau and Gray's Point, some 140 miles below the Merchants bridge at St. Louis and about 50 miles above Cairo. The Mississippi passes through a rock gorge between Gray's Point and Commerce, leaving a detached bluff against the head of the alluvial valley on the west. The problem of the Middle Mississippi lies between this gorge and St. Louis and requires heroic treatment.

The dynamic solution demands increase of volume and lower declivity. By the construction of a dam at some point in the gorge and assuming a lower level at St. Louis due to regulation, half the total fall at low water may be taken out, while the works already discussed increase the volume by 50 per cent. Regulation under these changes in condition should produce most important effects.

That twenty feet will follow is not determined. The increased low water volume should increase bar depths almost in proportion. The slope at high stages is not so much affected, nevertheless the energy is reduced and especially during the moderate and most persistent stages, and this makes for economy of prism. The less variation in volume is of itself a force of amelioration. It is reasonable to expect large results as compared to what may be obtained under existing conditions.*

Time will be required for readjustment and to carry out works of regulation. Meantime hydraulic dredges can, as now, meet the needs of navigation at low water, and the flow can be increased by such a reservoir policy in the Upper Mississippi as local reasons should justify.

No estimate need be made except for the dam and locks and for the lands to be affected, which are not of great extent in this nar-

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* The proposed dam would probably reduce high water declivity by 20 to 25 per cent, and the energy of the stream, as a whole, would probably reduce to some 70 per cent and require only that proportion of the former width for resistance. The general depth should be increased by some 40 per cent. Adding 50 per cent to the low water volume should increase bar depths in nearly direct ratio. It should be feasible, therefore, to obtain at least double the bar depths obtainable under existing conditions and as soon as the tendencies can be worked out.

row portion of the valley. The works of regulation are part of the present project.

Estimates for great and untried projects and dealing with such great forces have only a relative value. Nevertheless, the character of the problem between Chicago and St. Louis is such that what can be accomplished is as certain as about the great lakes and between the lakes and the seaboard, and experience is such that the estimates may be as safely relied upon. When all the data have been properly valued, the contingencies should not be large or the results uncertain. The only qualification pertains to the forty miles from the mouth of the Illinois to St. Louis, and it is possible to make a project which will eliminate uncertainty, but at considerable cost.

There is a determined and growing spirit for the development of the river southward from St. Louis, and little hesitation in Congress to supply the money. It is impossible to assume that, with the growing resources of the nation, this great artery shall be allowed to flow at will. Theories may be upset and effort prove fruitless, but only the egotist will set up his failures as the measure of future achievement and gauge all human thought by his own mental limitations. As long as water runs down hill and can serve a useful purpose, man will not cease in his efforts to utilize it. Then, from St. Louis to the Gulf of Mexico, it is only a question of some project which promises better results.

The distance from Chicago to St. Louis does not differ greatly from the distance from Lake Erie by the Erie canal to deep water of the Hudson river, and the investment of New York in her canal system is about the same as the cost of producing twenty feet between Chicago and St. Louis. Any depth, from ten to twenty feet, can be carried between these two cities for considerably less cost than across the state of New York by the Erie canal route. It would probably be less than by any route reaching the Hudson. The route would also have far greater capacity and quicker movement.

The physical conditions, as now understood, so far as they be practically available, do not seem to invite a present development much exceeding twenty feet in depth, to be obtained progressively, though this capacity must not be assumed to measure the possibilities of future achievement. The physical conditions by the St. Lawrence route and by the Champlain-Hudson branch, possibly by the Mohawk, do invite ocean navigation of thirty feet and upward. The two propositions, so far as involving the conservation, not dis-

sipation, of lake water, are mutually related, and in public policy the problem of lake control cannot be narrowed to an expedient of local navigation.

The immediate achievement of fourteen feet, based on a policy of progressive development to twenty, seems to best meet the physical, the commercial and the financial conditions. At the same time, limitations on the genius of those who come after are to be avoided.

Public policy contemplates the utmost development of resources. How far nations may grow is simply a question of how much there is, how far man may utilize it, and how wisely the benefits may be diffused and continued. What may come in a thousand years, or even in a century, is a matter of public policy which the present achievement cannot hope to discount, but clear ideas of public policy will decide alternatives, avoid projects that mar or blight the future, and design along the lines of a continuous development, so that evolution may proceed without loss to the final demand. The man who seeks to give direction to great movements without clear ideas of public policy and the moral force to abide by them, is but a parasite guided by his appetite.

Mr. C. H. Tutton—I have been forcibly impressed by Mr. Seddon's paper on employing the St. Francis basin as a site for impounding reservoirs, and since nothing can be said against reservoirs, where, as in this case, they are shown to be feasible, heartily concur with the most of his remarks, but particularly with that, that "every dollar the government has spent and is spending on the front levee line * * * is probably adding ten dollars to * * * the cost of a reservoir system here * * * when the educational flood at last comes that makes the necessity of this reservoir system fatally apparent."

The raising of high water on the Mississippi by the system of levee protection is but a reproduction of what has been observed and recorded in France and other countries. The Loire, for instance, whose low water width is from 1,000 to 1,600 feet and overflow width from 2,200 feet to nearly four miles, has been leveed since 1706. Along about this time, and for a century following, they were from 19 to 21 feet high in places; averaging 15 feet in 1759; but being overflowed by the flood of 1846, they were raised some 3 feet, which was again shown by the flood of 1856 to be from 8 to 12 feet too little. It is plain to be seen that this was no more than a natural consequence of reducing the overflow width by nearly two-thirds, as is done by the levees of today. (Lechalas,

Hydraulique Fluviale, p. 180.) In the larger Mississippi we would expect a greater change, and Mr. Seddon's remarks confirm this view.

Individually, I would suggest the abandonment of the idea of using this St. Francis basin channel for slack water navigation, substituting therefor an application of the principles laid down by M. Fargue (Ingenieur en Chef des Ponts et Chaussees) and which has been so successfully applied to the Garonne (see "Etude sur la largeur du lit moyenne de la Garonne," Annales des Ponts et Chaussees, 1882; also Lechalas, Hydraulique Fluviale, pp. 372 et seq.; also Flamant's Hydraulique, pp. 311 et seq.), to the natural bed as controlled in its height by the proposed St. Francis reservoirs. I believe that this system could be applied so that an enormous amount of dredging could be entirely dispensed with, and that the annual saving in dredging alone would repay the outlay on the reservoir, if not the entire system. I am not so sanguine of the permanence of the slack water channel through the basin.

I understand Mr. Seddon to say (see page 276) that a portion of the lower end of the St. Francis basin is now closed by levees. If this be so, I predict that his "educational flood" is much nearer at hand than it is pleasant to anticipate.

The whole subject has been treated very ably by Mr. Seddon, and his suggestion, even neglecting the fancied improvement above presented, is worthy of far more attention than it is likely to receive at the hands of our financeering representatives in Washington. He deserves the thanks of the entire country, and particularly those of the residents of the Mississippi Valley, for thus fearlessly sounding the note of warning.

Mr. R. E. McMath—My occupation of late years has separated me from the consideration of these questions, but I have found the time to read Mr. Seddon's paper, and have done so with much interest. He has followed out the line of reasoning that I started on many years ago, and has developed propositions which I foresaw were of sufficient practical importance to justify study.

The possibility of utilizing the St. Francis basin as a reservoir is certainly worthy of more than a mere discussion, and actual development of the possibilities by surveys should be made. For an application of the system of holding waters in reserve the St. Francis is admirably located, and probably well adapted by its profile and sections of its basin to that use. The water impounded could be delivered at the point where it is needed and the time would be subject to complete control.

As such a project would give a deep waterway over a large part

of the line between the Great Lakes and the Gulf of Mexico the consideration of this waterway as a whole is a part of the question. For this reason, Mr. Cooley's discussion is a most important supplement to the paper. He outlines for the Illinois river, projects which have been clearly in view for some fifteen years; and for the intermediate link between the mouth of the Illinois and Cairo he gives plans that are at least engineering possibilities.

It is to be hoped, therefore, that, altogether, this paper may be a factor in bringing about a general review of the existing projects along this whole line—projects which, perhaps, were well enough some twenty-five years ago, when they were first formulated, but to follow them further is to ignore the experience gained in the last quarter of a century.

Mr. Isham Randolph—Expenditures for the improvement of the Mississippi River and its preservation as a navigable stream have been made by the United States government year by year for the last 20 years, until the aggregate of all the appropriations for that purpose reaches $40,000,000, and today there is no greater depth for navigation than there was when the first appropriation was made. The thoughtless exclamation rises to the lips: "For what purpose was this waste?" but waste it has not been, since it has been only the payment for education in the school of experience; dear it may have been, but worth all it has cost. In October, 1897, as the representative of the Sanitary District of Chicago, I attended the Deep Water Ways Convention in Davenport, Iowa. The most striking address made before that convention was that of Judge Taylor, chairman of the Mississippi River Commission. He told of the work of that commission, of its sundry ventures and its manifold failures. From his point of view, the only success they had had in bank protection was with the willow mattress, and this mode of treatment was limited, first by the supply of material for making the mattresses, which would be exhausted in protecting a small fraction of the work to be done, and second, by its great cost, which was practically prohibitive. The only ray of hope which he saw for navigation, above the horizon of oft-repeated failure, lay in hydraulic dredges of the "Beta" type, a fleet of which, he thought, could successfully maintain navigation throughout the river at the low water stage. Since that time I have heard nothing to combat the gloomy views of the judge, and much to strengthen the idea that the wealth of the nation would not suffice to produce and maintain deep water in the pathway of the "Father of Waters."

The recent perusal of the paper in which Mr. James A. Seddon gives the conclusions at which he has arrived after long years of

patient observation conclusions which he supports with arguments sustained by cited facts reveals the first well considered project for maintaining an equilibrium between flood and low water stages in the great river, which has come under my observation.

To impound the surplus waters of flood periods in great storage reservoirs is certainly practicable, and it is no less so to feed the waters, so stored, back to the channel, and thus make good the deficiency in flow which obtains during the dry periods of the year. The estimate of cost placed upon this system of reservoirs, by Mr. Seddon, is conservative and well within limits for which the work can be let to responsible firms of contractors. Mr. Seddon's paper is radical in its originality, and the courage of the author's convictions is sustained by the evidence which he arrays in their support. He breaks away from the beaten track, discards old traditions and opens the portals of hope to those who have at heart the development of our great mid-continent by cheap transportation from its center to the sea.

This presentation amounts to a demonstration that deep water can be secured and maintained from Cairo to the gulf; and if from Cairo to the gulf, why not from Cairo to Grafton and from Grafton to Lockport? The heaviest link in the chain from the Great Lakes to the Mississippi has been forged by the Sanitary District of Chicago. A single municipality has cut through the great divide. Thirty million cubic yards of glacial drift is piled high upon the prairies and 13,000,000 cubic yards of shattered rock stretch down through the Desplaines valley, and at the bases of these newly made mountains flows a river whose source is the Great Lakes. This river offers flotation to the largest craft which our lake ship builders have ever launched, and it is today the largest artificial channel in existence. For this river Chicago has paid $33,000,000.00 and she is spending millions more to make the Chicago river a fitting entrance to its revolutionary extension. Under the auspices of the trustees of the Sanitary District she is widening the river to 200 feet, deepening it to 26 feet and removing all center pier bridges, and substituting therefor bascule bridges, the advantages of which to navigation are self evident. All of this Chicago is doing, and she stands ready to give all these results to the United States government, and in return she asks only that what she has so grandly inaugurated this government will carry to completion in the interest of all the people of the great middle west. It is my conviction that a deep waterway across the State of Illinois would be worth all it could possibly cost, within the limits of the most liberal estimates which have ever been placed upon it, even if there were no Mississippi to receive

its effluent waters, and no hope of ever floating a craft beyond the line which limits the sovereignty of the commonwealth. To the State it would be worth the outlay, even were the last cent of the cost drawn from its own resources; worth it in commerce which would be born of opportunity; worth it in lands reclaimed; worth it as a minimizer of freight rates, because of the competition which would then exist between railroads and the cheapest mode of transportation known to commerce.

But this channel which is to *be*, and I say it with the emphasis of a deep conviction, is not for the State of Illinois, but for all the States of the Mississippi valley, and not for these alone, for every addition to the riches of a State is but a fresh contribution to the wealth of the nation; and no outlay which the nation can make has in it the promise of richer returns for the investment than has this project of a deep waterway from the lakes to the gulf. Our rulers stand ready to build an isthmian canal at a cost in excess of $100,000,000.00 and the people give them godspeed in the undertaking. For less money this great interstate channel can be made a success, and its completion means infinitely more in substantial returns to the nation than does the opening of a highway through which ships may pass between the oceans which bound our coast lines, east and west. Our sanitary canal stands as a great forward movement in the arts of construction. There was a demand for economical methods, and American genius met those demands as American genius meets every demand upon it. New ways of doing things were inaugurated, new machines were devised, bold expedients were resorted to, failures were few, and the triumphs of that American genius were many, in witness whereof our man-made river is flowing today through its channel.

We've digged it through the prairie,
  We've hewn it through the rock,
We've walled its sides with masonry,
  'Twould brave the earthquake's shock.

And for economy of construction and successful achievement it stands without a parallel. The lessons it has taught shall not be in vain, and the channel which is to be, and which is to receive its waters, will be built better and at less cost to the nation because the men who will build it have the dearly bought experience contained in these lessons to guide them in their work.

Mr. Thomas T. Johnston—Great credit is due Mr. Seddon for his clever presentation of the flow variations of the main rivers of the Mississippi valley, from which can be deduced at a glance many

important conclusions as to the merits of reservoirs as a factor in modifying high water and low water river heights and volume of flow.

Evidently, headwater reservoirs, in order to modify materially the heights and flow of the Lower Mississippi, would have to be of such general and extensive application to all tributaries that their adaptability becomes impracticable. Mr. Seddon's discovery and determination of the physical fact that a system of reservoirs can be located in the St. Francis basin having a capacity sufficient to so materially modify high water conditions south of Cairo, and low water conditions south of Helena, opens the way for projecting other or auxiliary methods for the improvement of the Lower Mississippi, which have not hitherto been the subject, at least, of official mention, although, in the light of present facts, entirely worthy thereof.

It was about 1880, or a year or two earlier, that the government entered upon the improvement of the Mississippi river below St. Louis with something like a fixed purpose. Confronted with a problem the limitations of which were essentially unknown the engineers, at first through the agency of the Corps of Engineers, U. S. A., and a little later the Mississippi River Commission, set about investigating the subject to some extent. Parties were organized and placed in the field in 1878–79 to measure various physical elements of the Mississippi and its main tributaries. Cross-section and its changes, flow of water with its velocities and directions of velocities, water surface elevations, sediment in suspension, topography slopes, and anything else that could be thought of were some of the subjects for measurement, in as many or more different ways as there were subjects, and as the ingenuity of the engineers could devise. Overflows attending floods, high and low water conditions and other physical phenomena were investigated. Experimental works of construction were undertaken, in order to learn their utility as river improvement devices. Various engineers were assigned to works at various points, essentially with carte blanche to execute such work as they thought best, and all in an experimental way. Having been identified with these earlier studies for some years the writer knows something of the bewildering mass of data accumulated in the course of several years, and can testify to the seemingly hopeless task of correlating its elements in a way to arrive at tangible information in a form useful for practical application.

It fell to the writer's lot to determine the physical dimensions of the Chicago drainage canal, and its collateral works known as the diversion of the Des Plaines river, the improvement of the Des Plaines river through Joliet, the improvement of the Chicago river for a capacity of 300,000 cubic feet per minute, etc., etc., after

some seven years' continuous study of the physical data collected for the Mississippi river improvement, and it has been his privilege to follow this work to its successful conclusion and demonstration of the correctness of the calculated elements. The hydrology and physical characteristics of the region affecting the designs involved in the drainage canal were investigated and studied in manner and form corresponding to the afore-described investigations and studies for the Mississippi. Nothing could be more striking than the distinctive difference between the two undertakings, viz: In the case of the drainage canal the data was within such limits that it could be, and was, correlated in a manner to lead to tangible and definite results. Width, depth, grade, stability of construction, satisfactory and definite results, assurance of permanency and utility of the work and the wisdom of the expenditure were things all pre-determined before the work was undertaken, and the engineers proceeded with full confidence in themselves and in the results. In the case of the Mississippi, while much has been learned, still the engineers have not been able, after twenty years of investigation and study and experimentation, to agree among themselves or with others upon any plan of works the results to follow from which can be confidently anticipated. The engineers have done the best that could be done under the circumstances, but the nature of their problem has been so stupendous and unusual that the failure as yet of a definite solution is not a matter of surprise.

The course of procedure adopted, largely forced upon the engineers before investigations and studies could be completed, has been, (a) to prevent overflow into the country adjoining the river by means of levees at or near its immediate banks; (b) the increase, to a very moderate extent, of the navigable depth at a few of the most shallow places by means of dikes, bank revetments and training works; (c) to prevent bank erosion at certain points with sundry purposes in view; (d) and, latterly, to erode annually, by means of hydraulic dredges, temporary channels at the most shallow points along the river. Protection from floods, and a possible navigable depth of ten feet at low water, seem to be the real aims, although a theory has been advanced that by confining the flood waters to the river channel and holding the river to a fixed location the tendency will be to lower the plane of the river and, possibly, in a general way to equalize the depths along the river and thus increase the navigable low water depth.

The levee construction, (a), has proved to be more of a task than anticipated, as to height, cost of building and cost of maintenance, and many doubt the commercial merits of further endeavor to bring the work to a conclusion. Certainly, it would be highly

desirable to substitute some other construction that would accomplish the end in a more satisfactory manner, especially if it would remove the ever present menace of crevassed levees which must have existence if the existing project be carried to a conclusion. The endeavor to improve the navigable depth, (b), at a few stated localities has proved to be expensive tentative work, doubtful as to commercial advantage, and essentially impracticable in any reasonable length of time and at any reasonable expense if made generally applicable to all shallow places. The protection of banks, (c), from erosion is confessedly impracticable at any reasonable expense and in any reasonable time. The annual erosion of shallow places, (d), in the absence of anything better, is the most promising in commercial utility of any of the elements of the policy of the past. The depth to be obtained is small, however, and, as in the case of levees for flood protection, something better would be highly desirable.

Looked at from any point of view, the results of past efforts for improving the Lower Mississippi are somewhat disappointing though far from discouraging if a broad view be taken of the difficulties that had to be met. It would be highly improper to indulge in criticisms of the course that has been pursued. It is, however, entirely proper to discuss any suggestion giving promise of a better project, especially in view of the tentative nature of all that has been done or that can fairly be anticipated, as indicated by the contrast between the Chicago drainage canal project and the Mississippi river project.

Mr. Seddon's suggestion involves a far more radical protection from flood waters, and a greatly more radical improvement of navigable depth than anything hitherto contemplated, and if it is feasible, with sufficiently definite results to be expected, at anything like the estimated cost, then it would be well worth while to throw away all that has been expended in the past, and take up the suggestion. This is true, even if the results to be hoped for as a consequence of the policy of the past were certain of realization at the estimated cost. No criticism of past methods is involved. It is simply a much better project recently evolved.

The suggestion will, however, bear close investigation before adoption. Only the general and interesting feature of feasibility of storage is announced. Many collateral considerations are involved.

Primarily, there is conflict with the fundamental theory upon which the existing project was based, viz.: "That the river being confined, in all its volume, to a single channel, the tendency will be to lower the plane of the river and generally equalize depths

along the river to the end that low water depth will be increased." The converse has been stated, "that a division of the flow of the river will tend to cause the bed of the river to rise and further aggravate the difference in depth along the river." Much has been found in support of this converse by the instance of the division of the flow of the river at the mouth of Red river, where a large flow had existence into the Atchafalaya. However, as Mr. Seddon does not propose the diversion of any great volume, compared with the whole flow of the river, and since, in ordinary years, this flow from the main river will simply be at high flood crest, it is not probable that his idea constitutes any material infraction of the principle of the old theory. Some computations along this line would be interesting and instructive.

Perhaps the most difficult element to be encountered in carrying out this suggestion will be found in the entrainment of the water from the river in the vicinity of Cairo, not so much on account of the excavations and dams to be constructed, as on account of the form the slopes of the river will take during the period of entrainment. Here, again, some figures would be instructive. It may be said, however, that unless the bed or plane of the river be changed, the order of slopes would be affected only during the period of entrainment. At times of extreme flood, when it is desired to lower flood level at Cairo by ten (10) feet, without a corresponding lowering of level at points upstream in the Ohio and Middle Mississippi, it would seem that there would be a heavy concentration of slope immediately above the junction of the two rivers. The change of velocity of the water due to subtracting the upper ten feet of cross-section in the region in question, and running all the water through the smaller sections, would not be great, so that the resistance to flow at any section would not be very greatly increased. The necessary result would be the distribution of this ten feet of slope for a greater or less distance upstream—doubtless so far that its influence in an objectionable degree might be essentially nil.

Another difficulty will be met in conducting the operation of entrainment of water at Cairo in different years. The floods of some years do not reach any considerable height, as in 1879, in which instance, in order to fill the reservoirs, Mr. Seddon would have to place his sills lower than contemplated in his paper. This is not serious, however, for proper disposition, to meet these contingencies, in the design of entraining gates and dams can be made. Computations would be instructive here again.

Should Mr. Seddon's suggestion be given application, it may very properly be regarded as an auxiliary to the existing project.

That is, work could be continued and maintained along present lines as nearly as practicable, in the light of a flood height at Cairo ten (10) feet lower than hitherto.

There cannot, of course, be any question about the feasibility of constructing the reservoirs as suggested, and letting the water out of them in proper form.

The estimates given, though rough and doubtless too low, nevertheless show that the cost of the work is entirely within satisfactory limits. Suppose the results anticipated could be secured at twice the cost, the investment is still meritorious. Looked at from a commercial standpoint, the scheme has one great merit, viz.: the generation making the expenditure will live to enjoy some of its benefits. Ten years would easily suffice for construction. Again, the successful completion of such a project would develop the adjacent country as to usefulness and value to an extent that would be more than equivalent to the acquisition of a Cuba, or the Philippine Islands—and there are many who believe that, like charity, expansion should begin at home.

CLOSURE BY MR. JAMES A. SEDDON

It is very gratifying to the writer to find that the engineers with whom he began his studies of these rivers in the early eighties, so fully appreciate the importance of his conclusions in regard to the improvement of the Lower Mississippi. To Mr. Cooley, Mr. Johnston and Mr. McMath he owes the important fact that he started with comprehensive views. Building, then, on their foundations, he in no way wishes to claim an exclusive credit in his final results, but to fully share it with them and other earnest workers in this line whose observations and studies he has profited by.

Noting first, however, some special points raised in the discussion, the writer is not familiar with the conditions in the European rivers cited by Mr. Tutton. He has not been able to get hold of enough data to really study such rivers, if, indeed, the data has ever been taken. And as there is more than a life's work in the data of the Mississippi system, for years the writer has confined his studies simply to that field.

For a deep waterway from Helena up, however, the necessity for a slack water system through the St. Francis reservoirs is plain. Below Helena the low water flow, with the St. Francis reservoirs, will be some 300 thousand cubic feet per second, while from Cairo to Helena it will be but 100 thousand, and with the original slope unchanged in this reach of river it cannot be made a

waterway of depth equal to that from Helena down, though the greatly reduced floods will not tear up its bed and scatter its channels to the same degree, and it will certainly be a better river than it is at present.

In regard to Mr. Cooley's view of headwater reservoirs as a wise public policy to be followed through generations, the writer does not materially differ from him; and, indeed, as far as systematically storing the flood waters in the arid regions is concerned, he thinks it should be commenced at once. But the improvement of the Lower Mississippi is in progress, and the writer is considering alternative projects. The next Congress will be called on for another four years' continued appropriation of some $10,000,000, and the question of how this is to be expended is a pressing one.

Indeed, the writer wishes again to emphasize the immediate need of a revised project of the Lower Mississippi. Up to the St. Francis basin, all that the government has spent on levees can not be said to have been misspent; it has more than paid for itself in the protection that it has given the valley, and while some of the present levee heights will not be finally needed, they will be needed for a continued protection until the St. Francis reservoir system is completed.

But the case is different with what is now being expended on the front levee line of the St. Francis. Every addition to that, is raising the extreme flood level down the whole valley, and needlessly risking the protection that has been given it; threatening the lives and property of the many people there now behind these levees and below them, without any engineering justification whatever; while, as a business proposition, it is about the equivalent of draining a man's swamp for nothing and then buying it from him at its enhanced value to make a lake out of it.

Mr. Johnston's discussion brings out a number of interesting points: First, the original theory in favor of levees, that the increased flood volume would cut out the river and lower the levels of its flow. This has now been under close observation for some fifteen years, comparing the gauge and discharge data during the progress of the present levee system with the conditions preceding it. From these studies in general it may be stated that the increased flood volume does tend to materially lower the level of the given low water flow. But much higher flood stages accompany the restrained outflow, and if these are being lowered at all they are lowering very slowly, and promise little, if any, general relief in their final limits. This river bed, however, is markedly more plastic in its lower part than it is in its upper, and answers more readily to such flood changes, as in the case below Red River, noted by Mr. Johnston.

Altogether, however, the experience with the leveed river has been a disappointment to the friends of levees. Some comfort was taken at first from the fact that the low water level in cases was unquestionably lowered; but when this is recognized as a condition incident to a marked increase in the rate of erosion and the cost of maintaining a levee system on these caving banks, it is not encouraging. Indeed, in many respects, the experience with levees was more nearly outlined by Mr. McMath in 1884, in his paper,* "Levees, Their Relation to River Physics." And though his caution could hardly have been taken at that time without some plan that promised a flood protection to the valley, still his insight into the problem has been largely confirmed.

Mr. Johnston also calls attention to the important question of the high water regimen above the outlet, caused by the withdrawal of a large flood excess at Cairo. He notes correctly that the plans of the writer will throw the 10 feet cut off the top of the flood at Cairo into the extreme high water slopes of the lower Ohio. There is more or less of this here in any case, as the flood from the Ohio meets a high or low stage in the Middle Mississippi. Similar conditions also have been fixed by the overflows below Cairo, and from point to point along the whole course of the lower Mississippi, and again reversed in the reaches subject to inflow.

In the lower river these alternations of extreme flood volume are probably serious, but their effects are much less marked in the reach of the Mississippi below Cairo, and in the more stable regimen of the Ohio there is every reason to think that they will be insignificant. The writer is quite sure, therefore, that, in fixing once for all this variation in the lower Ohio, he has put it in altogether the best place for it.

Mr. Johnston, however, is quite right in questioning the level of 30 feet on the Cairo gauge as the fixed crest of this outlet. The writer did not intend to give the 30 feet as a final value, but merely to indicate the character of the work to be done there—a revetted bank, with weirs back from the river, in no way interfering with its regimen, and, indeed, out of water to something above the mid stages. It, perhaps, would have been better if the writer had said between 25 and 30 feet; but as this level can only be fixed after the capacity of the reservoirs is determined, in noting it he simply stated the higher limit.

Finally, the writer would deprecate Mr. Johnston's assumption that his estimates are too low. True, unforeseen obstacles may be met with; but in such tentative estimates of great works it is not uncommon to exaggerate the difficulties. Also, as noted by Mr.

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* See Journal of the Association of Engineering Societies, Vol, III, page 43.

Randolph, in the case of the Chicago drainage canal, they are on a scale that warrants the introduction of every economy in the cost of their construction. With the general character of this basin marked by the 14 days that it takes the flood waters to pass through it, there is little doubt in the writer's mind that it could be cross-ridged to hold a great storage capacity very cheaply. And starting with levees of moderate height, and bringing in hydraulic dredges to build on them, he can hardly think he has underestimated the cost of it. In this, also, he is glad to see that Mr. Randolph, with his wide experience in large works, confirms the writer's judgment of the matter.

So much for the special points raised in the discussion; but in addition to this, Mr. Cooley's contribution so greatly widens the scope of the writer's paper that it is now no longer simply a project for the Lower Mississippi, but a part in a deep waterway extending from the Great Lakes to the Gulf of Mexico; and as such is a matter in which the whole interior of this country is interested.

It is altogether nothing less than a project to bring a seaboard to the center of all the grain and ore and coal and timber in the great valley lying between the Rockies and the Alleghenies, and the final measure of its utility is today probably beyond the range of the wildest imagination.

It is interesting to note in Mr. Cooley's project, from Utica to the mouth of the Illinois, the same element of necessity for a deep waterway that the writer finds in the case of the Lower Mississippi. It is only in this way that the low lying bottom lands down that valley can be reclaimed and protected. But this deep waterway here is to be made by drawing on the reservoir of the lakes for its low water flow and dredging a suitable channel to take it.

The character of this 227 miles of the Lower Illinois is unique among western rivers. It may, perhaps, be best noted in the contrast between the three rivers, the Missouri, the Upper Mississippi and the Illinois, which meet to form the Middle Mississippi; in these the low water flow of the Missouri is some 25 thousand cubic feet per second; of the Upper Mississippi more than 30, while that of the Illinois was less than 1; and yet the three rivers had about the same navigable depths at low waters.

It is in this river, with little more than a tenth of a foot fall to the mile, that the Chicago drainage canal now promises to turn down an additional flow of 10 thousand cubic feet per second, and here Mr. Cooley well points out that a deep waterway is simply a matter of cutting the channel once for all with hydraulic dredges and turning in a sufficient flow to maintain it, while such a deep

channel in its turn will carry off the moderate floods of this river without any destructive overflows.

From Utica up to the drainage canal at Lockport the line is simply a plain slack water system of river improvement and can be given as great a depth as is wanted. It is, however, specially desirable that the full development of the whole route should not be marred by insufficient works in this division. To put in fixed locks and dams on this line that would have to be torn out and replaced by larger ones before they even came to their full service would be a serious mistake here.

Where, however, dredging the channels is all that is required, the work may be developed progressively. Thus, the present flow from the drainage canal will not maintain in the Lower Illinois more than about a 9 foot channel, and to get this will cost some $2,500,000 and take some four or five years' work with hydraulic dredges. By that time, however, the full flow from the drainage canal will be in sight, and cutting the channel some 5 or 6 feet deeper may be begun, giving in the course of some ten years about a 14 foot waterway there.

By that time, also, the St. Francis reservoir may be put in, with a complete flood and bank protection and deep water to Helena, and the Lower Mississippi will be a river improvement finished with the exception of some $400,000 annually operating a dredging fleet in cutting the slack water channels from Helena to Commerce. All this, also, may be done with less than twice the present annual rate of appropriations for that river, or but little more than double the estimated yearly cost of maintaining its levee system when completed.

With the Lower Mississippi then practically off its hands, and a gulf navigation in sight to Commerce, the government is free to turn its attention to developing the rest of this route to its full capacity. To carry a 20 foot depth down the Lower Illinois will take something like a doubled flow of lake water down that valley, and conditions around Chicago will then be developed that will make this additional flow very desirable. This also involves an artificial control of lake outlets and levels, which is even now being considered.

Here then, also, the problem of the Middle Mississippi may be taken up, and Mr. Cooley's plans for this are the first practical project that has been suggested for a really deep waterway over this route. Whether they are the best and the cheapest may be left for further study, and there is ample time to study them. For until the 20 foot waterway from the lakes to the Mississippi is in progress, from St. Louis down at least hydraulic dredges can keep open the 14 foot navigation through a large part of the season.

Altogether, then, the project for this deep waterway is a syste-

matic development of the whole route to its fullest capacity, the works to cover a period of some twenty years, and built upon the costly experience of the last twenty. It is only necessary that it should be reviewed as a whole, and the annual appropriations expended in harmony with the whole project. On it, then, increased usefulness will follow moderate initial expenditures, and a growing commerce which does not now exist will rise to enrich the enterprise and reward the labor of the whole interior.

From the estimates given, the total cost of this waterway from Lake Michigan to the Gulf of Mexico, some 1,600 miles long, and nowhere less than 20 feet deep at all stages, may be taken as something between $150,000,000 and $200,000,000, or only some three or four times as much for this national enterprise as the city of Chicago assumed in cutting for sanitary purposes the first 33 miles of it.

As a further comparison, it may be noted also that this estimate is but little more than the cost of building the Nicaragua canal. The first brings a seaboard to all the products of the interior; the second opens a new line of exchange to products that have reached the coast. Both are desirable, but the first has the larger claim, even aside from the fact that the dollar spent by this country on its interior waterway is both to have the waterway and to keep the dollar. Certainly, then, as Mr. Johnston puts it, in the matter of waterways, at least, expansion should begin at home.

ABSTRACT OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

A CONCRETE ARCH BRIDGE; TESTED AT THE EHINGEN WORKS OF THE STUTTGART CEMENTFABRIK, BY A. HOCH.

[*From Thonindustrie Zeitung, 1899, page 545.*]

To show the advantage of using a hinged arch and concrete of high tensile strength in the construction of an arch bridge of long span and small rise, an arch of (20 meters) 65 feet 7⅜ inch span; (1.54 meters) 5 feet ⅝ inch rise; (12 cm.) 4¾ inches thick at the crown; (22 cm.) 8¾ inches thick at the springing line, and (32 cm.) 12⅝ inches at the arch gaps was built and tested as follows:

The proportion of the concrete was 1 part cement to 7½ parts machine-crushed limestone. Instead of sand, about 30 per cent of screenings of the limestone was used. The concrete was made in a mixer and rather wet and attained a compressive strength of:

440 kg. per s. cm., or 6,258 pounds per square inch in 28 days.
480 kg. per s. cm., or 6,826 pounds per square inch in 3 months.
495 kg. per s. cm., or 7,040 pounds per square inch in 6 months.
506 kg. per s. cm., or 7,195 pounds per square inch in 1 year.
511 kg. per s. cm., or 7,267 pounds per square inch in 2 years.

It was decided not only to measure the deflections due to the loading but also those due to temperature. For the last mentioned reason, instruments for measuring were applied at the springing line and at the crown, by means of which motions of 1-10 mm., or about four thousandths part of an inch, could be determined accurately.

After the arch had been completed 16 days, the forms were removed and the arch sank 4½ mm., or about 3-16 of an inch, which could be ascribed to the motion of the abutments of from 1 to 1½ mm., or from four to six hundredths of an inch.

Twelve days after the removal of the forms, or 28 days after the completion of the arch, it was loaded with cement paving blocks to a height of 1.4 meters, or 4 feet 7 inches, between each course of

which a layer of sand was put. This loading stressed up the arch as follows:

LOCATION.	COMPRESSION.		TENSION.	
	Kg. per sq. cm.	Lbs. per sq. in.	Kg. per sq. cm.	Lbs. per sq. in.
Crown	148	2,105*		
Point N........	187	2,659*	28	398*
Point M........	163	2,315*	55	782*
Spring line.....	85	1,209	55	782*

The arch was subjected to this load for one year.

January 1, 1897, the indicator of the instrument for measuring thermal deflections was placed at zero at a temperature of zero Centigrade, after which the temperature gradually fell to 10 degrees below zero, on January 28, and the crown of the arch sank 10 mm., or 3/8 inch. With the increase of the temperature to 10 degrees above zero, in the end of February, the arch rose 15 1/2 mm., or about 5/8 of an inch. Unfortunately, the foundation of the arch was not built sufficiently strong, and the arch moved at the springing line, for which reason the arch did not rise as much as it sank.

For this reason, two iron ties were attached to the arch at the springing line, but even these did not entirely check the motion of the arch at the abutment.

At the end of April, 1898, the loading was resumed, and was continued till the middle of September, and the load was carried to a height of 3.4 meters, or 11 feet 2 inches. This loading stressed up the arch as follows:

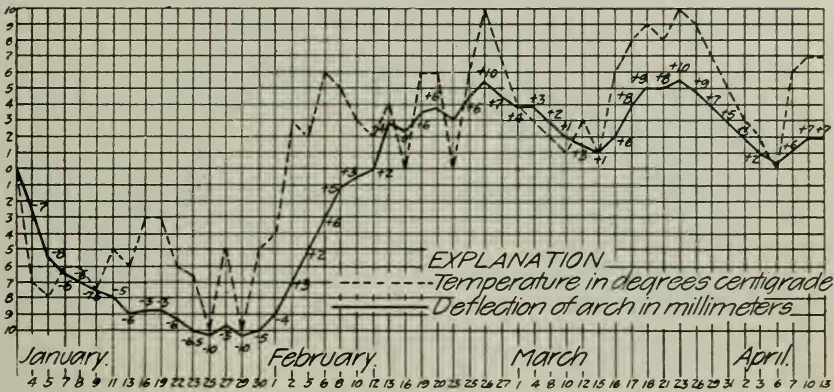
LOCATION.	COMPRESSION.		TENSION.	
	Kg. per sq. cm.	Lbs. per sq. in.	Kg. per sq. cm.	Lbs. per sq. in.
Crown	278	3,954		
Point N........	380	5,405	92	1,308
Point M........	335	4,765	130	1,849
Springing line...	183	2,602		

On September 2nd the unloading of the arch began.

In the graphical diagram showing the deflections of the arch, and the position it resumed after being released of its load, it will be observed that it did not resume its original position in regard to height, which may be ascribed to the reasons given above.

On the other hand, the concrete had not lost its elasticity, which was demonstrated by its motion after release of load.

DEFLECTIONS OF ARCH, DUE TO TEMPERATURE, WITH A LOAD 1.4 METERS HIGH.



Its greatest deflection occurred at a temperature of 15 degrees below zero, Centigrade, which was of short duration, and for that reason it did not come into full play.

In the course of this year the loading is to be resumed.

This experiment proves how necessary and indispensable hinged joints are for flat arches of long spans, and how much they increase the strength of the bridge.

Another argument in favor of hinged arches is the continued motion of the arch on account of temperature variations. In this arch a variation of one degree of temperature caused a motion of 1 mm. at the crown of the arch.

In regard to the use of rich concrete mixture, the stresses indicate the necessity thereof.

Three I beams of the lightest section were imbedded in the concrete in order to assist the concrete in tension, which it is demonstrated they did, for no concrete could stand a tension of 130 kg. per square cm., or 1,849 pounds per square inch.

Another argument in favor of rich concrete mixture is that iron and a rich mixture have the same expansion for heat and cold; and, besides, the cement keeps the steel from rusting.

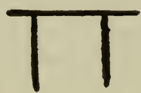
A. R.

TEST OF A CONCRETE BRIDGE WITH STEEL CHORDS, BY M. MOELLER.

[*From Deutsche Bauzeitung, Vol. XXXIII, 1899, page 337.*]

The firm of Drenkhat & Sudhop, at Braunschweig, Germany, tested a concrete bridge with imbedded steel chords (patent of M. Moeller) up to destruction.

This bridge consisted of two girders 20 meters long between supports, each girder showing a rectangular cross section and both being solidly connected by a concrete top plate 20 centimeters thick and 2 meters wide. This plate had to act as top chords and as bridge floor at the same time. The cross section of the bridge looked about like this:



In the lower part of each girder two steel ropes were imbedded, of 5 centimeters diameter and 14.23 square cm. cross section each. The top of each girder was reinforced by an I beam N. P. 20 (equal to an 8 inch I, No. 18) which had to transmit and equalize the influence of local loads. Each I beam consisted of two pieces spliced in the center of the span in such a manner as to transfer shear or vertical forces, but practically no moments. The continuity of the webs of the concrete girders was interrupted by circular openings, from each of which an artificial vertical cut through the concrete reached to the lower edge of the girder. By this arrangement the web could transmit compression stresses only, and all tension stresses had to be taken up by the steel wire ropes. The whole bridge, however, formed one monolithic body notwithstanding the openings and cuts in the webs. The distance from top of bridge to lowest edge of wire rope was one meter or 1-20 of the free span.

At the beginning of the test the stress in the steel ropes was 1,836 kilograms per square centimeter. Two concentrated loads of, together, 10,075 kg. brought this unit stress up to 2,650 kg., and the deflection in the center of the span was then 20 millimeters. After removal of said loads a permanent deflection of 6 millimeters remained, which, apparently, was the result of pressing the single wires of the ropes closer to each other and thus elongating the ropes without the elastic limit of the steel wires being reached. Loads were then put on again with the result as shown in the table:

Total live load.	Equally distribut'd live load per square meter.	The two single loads together.	Deflection in center of span.	Unit stres' in ropes per square centimet'r	Remarks about the concrete.
Kg.	Kg.	Kg.	Millimeter	Kg.	
22124	537	3866	34	3013	One of the foundations settled and moved sidewise.
					Crack in abutment.
33186	805	5799		3601	The first cracks in the webs.
44248	1074	7732	121	4190	The cracks in the webs increase slowly. The crack in the abutment measures 15 millimeters.
96780	2349	16910	320	7001	The concrete top plate breaks in a downward direction, in consequence of the excessive elongation of the ropes.

As the bridge was designed for a live load of 300 kg. per square meter, it stood about eight times the prescribed load before it failed.

At a deflection of 300 millimeters the concrete top plate was still free from cracks; ten seconds later, however, it broke down.

As in tests previously made the failure occurred, not in consequence of a break of the tension chords, but was caused by the excessive elongation of same, which produced bending and breaking of the concrete top chord.

Result: The girders stood the test well, with the exception of the deflection, which would have been considerably smaller if, instead of wire ropes, flat bars had been used. The allowable unit stress for steel wire ropes should, therefore, be somewhat less than twice the unit stress allowed for wrought iron.

V. B.

ABSTRACT OF MINUTES OF THE SOCIETY.

SPECIAL MEETING, June 13, 1900.

A special meeting (the 426th) of the Society was held in its hall at 8 o'clock, Wednesday evening, June 13, 1900, President Ambrose V. Powell in the chair, and 62 members and guests present.

The President called the meeting to order and then introduced the speaker, Professor C. R. Van Hise, of the University of Wisconsin, who gave an interesting and instructive talk on the subject announced for the evening, viz.: "Some principles controlling the deposition of ores." He presented drawings and diagrams illustrating the special features he had under consideration and delivered an able exposition of his views. The discussion was opened by Professor T. C. Chamberlain, of the University of Chicago, and was participated in by Professor J. B. Iddings, of the same institution, by Professor Farrington, of the Field Museum, and by Mr. L. L. Summers.

At the conclusion of the discussion, Mr. B. E. Grant moved a vote of thanks to Professor Van Hise. The motion was put, and carried unanimously.

The meeting adjourned.

SPECIAL MEETING, June 20, 1900.

A special meeting (the 427th) of the Society was held in its hall at 8 o'clock, Wednesday evening, June 20, 1900. President Ambrose V. Powell, in the chair, called the meeting to order and presented Mr. James A. Seddon, who read an abstract of his valuable paper on "Reservoirs of the Lower Mississippi River." Lantern slides of diagrams of flood combinations, etc., were thrown on the screen, and explanations given by Mr. Seddon. At the conclusion of this address, Mr. L. E. Cooley was called upon and ably discussed the subject at considerable length, and in a very interesting style.

Mr. Isham Randolph was next called upon and said: "I suppose you all realize, when you get on the question of waterways, that if Mr. Cooley gets a start there is nothing left for the other fellows to say. He has navigable waters on the brain." (Applause.) Mr. Randolph then read a discussion which he had prepared and which appears elsewhere in this issue.

The meeting adjourned.

REPORT FOR THE BOARD OF DIRECTION.

At a Board of Direction meeting, held on the 20th of June, 1900, William Henry Elliott was declared elected to active membership.

The following applications were received, read, and referred to the Membership Committee: For active members—Paul M. Chamberlain, Edward B. Ellicott, Josiah Gibson, Henry F. Baldwin; and for junior membership—William C. Bunnell.

At a Board of Direction meeting, held on August 6, 1900, the following named applicants for admission to the society were declared elected to active membership: Messrs. Paul G. Brown, Henry F. Baldwin, Josiah Gibson, Edward B. Ellicott and Paul M. Chamberlain. As junior, William C. Bunnell.

The following applications were received, read and referred to the membership committee, for active membership Harry L. Millerd and John T. Corbett; for transfer from junior to grade of active membership, Robbins Y. Maxon.

NELSON L. LITTEN, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL we have received the following gifts from the donors named:

A. Lincoln Hyde, The Inidikil System.
Board of Health, Manchester, N. H., Annual Report, 1899.
J. C. Houghton, Librarian, 37th Annual Report, Trustees of the Public Library of the city of Lynn.
U. S. Department of Agriculture, Methods of Constructing Macadamized Roads.
Carnegie Steel Co., Standard Steel Rails and Splice Bars, 1900.
W. S. Blatchey, Indiana Dep't of Geology and Natural Resources, 24th Annual Report, 1899.
Walter J. Graves, The Holding Power of Screws in Wood.
Institution of Naval Architects, 12 Papers read at the 41st Session.
Society of Engineers, London, Transactions for 1899, and General Index, 1857–1899.
George P. Nichols & Bro., 21 Periodicals.
City of Burlington, Annual Report of the Health Officer, 1900.
International Asso. for Testing Materials. American Section, Bulletins 8 to 18.
New Jersey Board of Health, 23rd Annual Report.
State Board of Health, Ohio, 13th Annual Report, year ending Oct. 31, 1898.
U. S. Department of Agriculture, The Use of Water in Irrigation in Wyoming.
State Board of Health, Ohio, 2nd Report of an Investigation of the Rivers of Ohio as Sources of Public Water Supply.
Michigan School Masters' Club, Proceedings, 34th Meeting, March, 1900.
U.S. Government, Report on Protection of Sacramento and Feather Rivers, Cal.
" " Examination and Survey of Mackinac Harbor, Mich.
" " Survey of the River Bank at Paducah, Ky.
" " Examination and Survey of Cheboygan Harbor, Mich.
" " Survey of Licking River, Kentucky.
" " Examination and Survey of Lower Willamette and Columbia Rivers, below Portland, Ore.
E. A. Bond, State of New York, Reports State Engineer and Surveyor, 1897-1898-1899.
War Department. Report of Chief of Ordnance, 1899.
U. S. Geol. Survey, 20th Annual Report, Part IV, Hydrography.
L. C. Fritch, Sec'y American Railway and Engineering and Maintenance of Way Association, Proceedings 1st Annual Convention, March 14-15, 1900.
Chicago Academy of Sciences,
Bulletin Volume 2, No. 3.
Bulletin No. 4, Part 1.
Hon. Isaac Taylor, Report of the Special Commission, Chicago Drainage Channel, 1900.
U. S. State Department, Report by Elmer L. Corthell, Delegate of U. S. to the Seventh International Congress of Navigation, Brussels, Belgium, July, 1898.
Institution of Civil Engineers, London, List of Members of the Institution, July, 1900.

E. E. R. Tratman,
Report of the General Manager of Railways, Cape of Good Hope, 1898.
Annual Report Railway Commissioners, New South Wales, June 30, 1899.
Administration Report of the Railways in India, 1898-99.
John Crerar Library, The, A List of Books in Reading Room, January, 1900.

NEW EXCHANGES.

The Official Guide of the Railways, etc., of the United States, Porto Rico, Canada, Mexico and Cuba. Monthly.
Cement and Slate, Allentown, Pa.
Mining Reporter, Denver, Colo.

LAKE EXCURSION.

Under the direction of the Entertainment Committee, of which Mr. J. J. Reynolds is chairman and Messrs. Isham Randolph and Robert W. Hunt are members, a successful and enjoyable excursion on Lake Michigan was had on Saturday, August 11, 1900. The day was one of extreme heat. The committee engaged the steamer H. W. Williams, which, with a party of 140 ladies and gentlemen, including many children, left the dock at the north end of Rush street bridge, at 4:30 p. m., and was soon out in a deliciously comfortable atmosphere, and the hot, humid condition left on shore was remembered only by way of comparison. A lunch was served at 7 o'clock. At 8:30 a heavy rain storm came up, but it did not seriously interfere with the enjoyment, as all were comfortably housed in the cabin. Music added to the pleasure, and the trip, concluded at 9 p. m., was pronounced an enjoyable affair.

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VOL. V. OCTOBER, 1900 NO. 5.

XCVII.

MONIER CONSTRUCTIONS.

By E. Lee Heidenreich, M. W. S. E.

(Supplement.)

Read September 19, 1900.

Before submitting the different formulæ used in the calculations of Monier constructions, I will refer to the written discussion submitted by Mr. H. W. Parkhurst when I read my first paper before your society June 6. Mr. Parkhurst regards the use of Monier constructions for culverts, arches, etc., in a sense experimental, because neither of the materials, steel or concrete, are used in sufficient quantities to be durable without the aid of the other. The judicious combination of the two materials constitutes what is called "Monier constructions," and as for its durability I can cite a great number of examples, but will, for the present, merely refer to the following:

In 1889 the railroad from Guaira to Caracas and from Caracas to Antimano, in Venezuela, was built, and one of the principal difficulties was to dispose of the considerable quantities of water which passed through the different embankments during the violent tropical rain storms occurring in that country. The culverts had to be made as much as 10 meters wide and 5 meters high and it was found the best to resort to Monier constructions. The use of Monier constructions on this railroad was so satisfactory that it since has come into universal use in Germany, Austria and Hungary. I will simply call your attention to the ease with which the different parts entering into a Monier culvert can be transported, as compared with the transportation of cast iron pipe. The economy also is effected by rapidity of construction. A cast iron pipe must be ordered from the foundry and sent long distances to its destination, while a Monier pipe can be built on the premises and if it is to be transported it weighs but one-half of the cast iron pipe. For pipe, from 3 feet diameter up, Monier pipe costs about one-half of the cast iron pipe. The permanency of Monier construction depends upon its design. If properly designed it would be indestructible. If the cast iron pipe is not properly designed it will break also.

I will refer to another instance of the manifold applications of Monier constructions, namely, for cylinders built on the Monier system to replace cast iron in cylinders for bridge piers, and also Monier pipes for the protection of piling against the teredo worm. A couple of months ago I had a conference with Mr. Chas. Sooysmith, the well known consulting engineer in New York, regarding the utility of Monier cylinders as shells for concrete piers under tall buildings or heavy abutments. The secretary of the Western Society of Engineers, Mr. Nelson L. Litten, called my attention to an article by Mr. Pat Doyle, C. E., of Calcutta, India, in his *Indian Engineering*, of June 23, 1900, in which Mr. Doyle describes bridge pier cylinders built at New South Wales on the Monier system, and also refers to the fact that at the same place the piling was protected against teredo by means of Monier pipes. The paper is very interesting, and I take the liberty to reprint it here, knowing that it will be of vast interest to the engineers of this country:

MONIER CYLINDERS AND PILE COVERS.

[*From Indian Engineering, June 23, 1900.*]

The Cockle Creek bridge in New South Wales is worthy of notice by reason of the use there of cylinders built on the Monier system instead of cast iron (whereby a saving of 264 pounds, 5 shillings was effected on two small piers alone), and of Monier coverings to protect the timber piles from the attacks of the "cobra" (insect). The system, which is fully described below, and illustrated by the plate, is very efficient and capable of extended use.

This bridge (see plan), though not of importance in point of magnitude, being only 343 feet in length, and costing 3,800 pounds, is of considerable interest, owing to the use in its construction of Monier cylinders in lieu of cast iron, and also Monier pipes as a protective covering for the piles. The difficulty of protecting timber piers in salt water from the attacks of the "cobra" leads to the use of the cylinders, generally of cast iron filled with concrete, for important piers such as those under truss spans, and the cost of the cast iron cylinders has been a very serious item. The success of the Monier system in connection with pipes of all sizes suggested that it might be used as a substitute of cast iron in cylinders, and it was tried for the first time at Cockle Creek as now described.

The main piers of the bridge each consist of two cylinders 3 feet 6 inches internal diameter, and 2¼ inches thick, constructed on the Monier principle, and having one layer of wire netting (1 inch mesh and 16 gauge), and two spirals of 10 gauge steel wire wound completely round the cylinder, the turns being 1 inch apart. The longitudinal connection is formed by six steel bars 1¼ inch by ¼ inch placed between the wire spirals; these bars are so arranged that those of adjoining lengths of cylinder can be coupled together by means of a small fishplate and steel wedges.

In sinking the cylinders the joints were made with red lead to prevent leakage, and it was found that, when several segments were joined together, they could be lifted without disturbing the joint. A cast iron cutting segment was used (see Fig. 4) to protect the bottom edge of the cylinder, and as a precaution against damage by the men's picks, a thin steel plate guard was provided for the inside of the cylinder up to a height of 4 feet, but this was not found necessary. The cylinders were sunk through gravel, sand and clay, 36 to 41 feet below the water, and as it was found possible to keep them pumped dry if well pressed down by means of screw jacks, the air lock was not required. When a satisfactory foundation was reached the cylinders were filled with concrete in the usual way, the inside surface of the Monier being carefully cleaned to get as good a bond as possible with the concrete.

The cost of these cylinders, delivered at site, was 24 shillings per foot, as against

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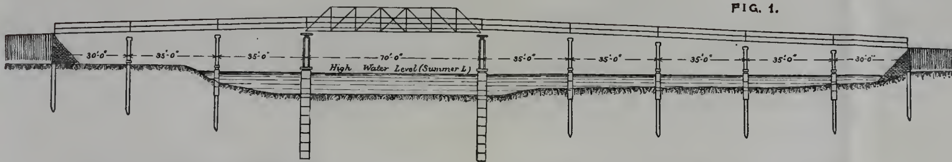
Heidenreich—Monier Constructions.

COCKLE CREEK BRIDGE, N. S. W.

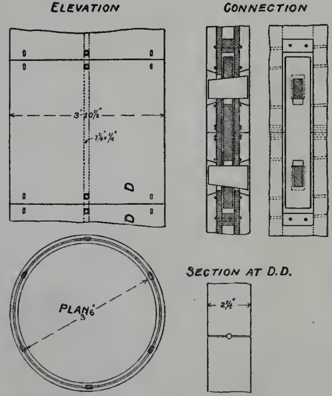
SKETCH SHOWING USE OF MONIER CYLINDERS AND PILE COVERS.

ELEVATION

FIG. 1.



DETAILS OF MONIER CYLINDERS



C.I. CUTTING EDGE

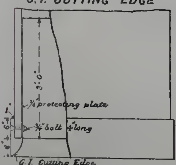
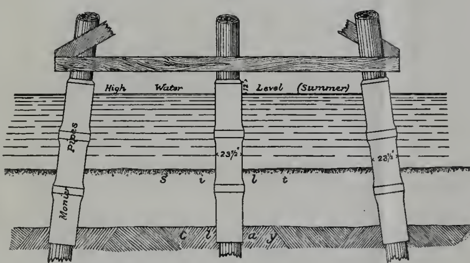


FIG. 4.

PIER



DETAILS OF PILE COVERINGS.

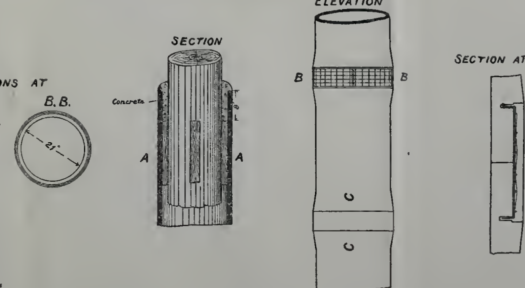
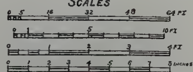


FIG. 2.

SCALES



3 pounds per foot for cast iron cylinders of the usual type, making a saving of 264 pounds 5 shillings on those two small piers alone, and there is no doubt that their use in suitable localities will result in a very large saving in future.

Hitherto, where protection from the teredo has been necessary for timber piles, Muntz metal has been generally employed, or, in some cases, earthenware pipes filled with concrete; but these latter, owing to their fragile nature, and the difficulty of making a joint with the necessary longitudinal strength, have not proved very satisfactory. At Cockle Creek the experiment was made of using Monier pipes for a pile covering. These are exceedingly strong to resist fracture, and even if cracked do not fall to pieces; they can be joined so as to have a good strength longitudinally, which makes them easy to handle; and, what is most important, a series of piles can be forced down with screw jacks without danger of cracking.

Fig. 1 on plan shows the Cockle Creek bridge, in which 5 timber piers, having 3 piles in each, or 15 piles in all, have been protected by Monier pipes.

The formation is sand mixed with vegetable matter, overlying stiff clay to a depth of about 5 feet, and it was considered desirable that the piles should be protected down to the point where they entered the clay, so as to provide against removal by scour of the soft upper strata. The piles were of ironbark, about 40 feet long, 14 inches diameter at the small and 18 inches diameter at the large end, driven 15 feet into the clay. From the level of the clay to high water, 4 hardwood battens were spiked to act as guides for the pipes, and the piles received a coating of Stockholm tar before driving. Driving having been completed, a small platform was attached to the pile above high water, and upon this were erected, by threading, over the head of the pile, a sufficient length of 21-inch diameter Monier pipes to reach from high water to the clay bed. The pipes were then joined with a wire netting cover and cement, the joint being the ordinary Monier pipe joint, swelling the diameter of the pipe about 2 inches; but it may be mentioned that the contractors for the pipes have made an improved joint (shown in Fig. 2), which will suit better and be more sightly. While the joints were setting the cap valves were fixed on to the piles, so as to bring them into position, and avoid movement after the pipes were sunk. The platform was then removed, and the pipe casing lowered by means of hooks under the bottom length of the pipe, until it rested upon the bottom. A jet of water from an inch and a half pipe was then worked round the bottom of the pipe casing to loosen the material, and pressure was applied by means of screw jacks at the top, when the casing sank easily to the clay bottom. The space between the casing and the pile having then been scoured out with the jet, was filled with clean sand, finished with 9 inches of concrete at the top to form a cap. The casing presents a neat appearance, and no doubt will prove of great durability, probably outlasting the pile.

The pipes used are constructed on the usual Monier principle, being 1¼ inch thick, of cement mortar on a groundwork of wire netting, 1¼ inch mesh and 16 gauge.

Referring to Mr. Ralph Modjeski's paper, a very interesting discussion, it shows the great advantage of the Monier system by being so comparatively simple, consisting of nothing but plain round iron rods encased in cement mortar.

Referring to the discussion submitted by Mr. J. B. Johnson, will repeat that the Monier construction is not a concrete construction but a fortified mortar construction, and, therefore, as Mr. Johnson states, there is no necessity for twisting the rods or making them crooked or grooved. As he states: "Where cement mortar alone is used, the adhesion to plain wires will be sufficiently high to warrant the use, but in concrete the adhesion to plain surfaces will be found insufficient." The proprietary name, "Monier constructions," certainly cannot harm the system, and under this name it has gained its reputation and universal application in Ger-

many, Austria, Hungary, Denmark, Norway, India and Australia. Mr. Modjeski suggests that I again come before the society with a treatise giving formulæ, tables, etc.

Mr. M. Koenen, in 1886, published a method of calculating Monier construction in "Centralblatt der deutschen Bauverwaltung," and Mr. Edvard Kolderup, captain of engineers in the Norwegian army, in his book, "Monierkonstruktionerne," in 1893 gave an extract of Mr. Koenen's calculations without going into details as to the deduction of the formulæ, thus saving the intricate theoretical deductions with their integrals and differentials. I will submit Mr. Koenen's easiest and most practical formulæ, and will take each form of construction by itself.

Monier Plates.

A horizontal plate supported by both ends will, when subjected to an evenly distributed load, cause horizontal stresses within the plate, acting in opposite directions as compression in the upper and tension in the lower half, increasing from the neutral axis toward the outsides of the plate where they attain their maximum.

If k represents the safe stress, in kg. per $cm.^2$ (Fig. 1), the stress p at a point e is found as follows:

$$p : k = x : \frac{t}{2}$$

$$p = \frac{2k}{t}\, x$$

in which t represents the thickness of a Monier plate.

If all compression stresses are summed up in a resultant T, calculus gives us

$$T = k\frac{t}{4}$$

and that

$$Z = \frac{t}{3}$$

All tension strains may be summed up in the same manner—and, of course, $S = T$.

Monier plates are based upon leaving the mortar to assume the entire compression, and the carrying rods the entire tension strains, and for this reason the rods are located at the point where the resultant tension S is found, or at ^{z} from the neutral axis. The maximum moment of the exterior forces being M_{max}, we have

$$M_{max} = \frac{2}{3}\, t\, T$$

$$M_{max} = k\, \frac{t}{4}\, \frac{2}{3}\, t$$

$$M_{max} = k\, \frac{t^2}{6}$$

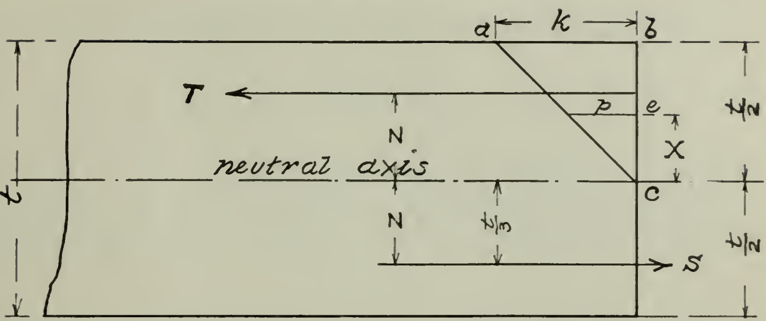


FIG. I.

hence

$$t = \sqrt{\frac{6\,M_{max}}{k}} = 2.45\sqrt{\frac{M_{max}}{k}}$$

If the maximum safe tension of the carrying rods is K in kg. per cm.^{2}, and F represents their area in cm.^{2}, we have

$$S = K\ F$$

As $S = T$, and $T = k\frac{t}{4}$, we have

$$K\ F = k\frac{t}{4}$$

$$F = \frac{1}{4}\,\frac{k}{K}\,t$$

If the width of our Monier plate is *b* in cm., we have

$$M_{max} = k\ b\ \frac{t^{2}}{6}$$

$$t = \sqrt{\frac{6\ M_{max}}{k\ b}}$$

If total area of carrying rods in a plate of the width *b*, is F_b, we have

$$F_b\ K = k\ \frac{t}{4}\ b$$

$$F_b = \frac{k}{K}\,\frac{tb}{4}$$

For Monier plates it is customary abroad to make

k=30 kg per cm^2 or 427 lbs. per square inch.
K=750 kg per cm^2 or 10,700 lbs. per square inch.

(K is made from 16,000 to 20,000 for arches and tanks.)

If we simplify matters by making b = 100 cm., we have

$$t = \sqrt{\frac{M_{max}}{500}} \;\ldots\ldots\ldots\ldots (1)$$

$$F_b = t \;\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where t is given in cm., and F^b in cm^2.

These are the formula used by Mr. Koenen.

These formulas Capt. Kolderup further simplifies as follows:

$$M_{max} = \frac{1}{8} Pl$$

P being total evenly distributed load in kg., and l length of plate in cm., hence

$$t = \sqrt{\frac{Pl}{4000}}$$

or with l in meter

$$t = \sqrt{\frac{Pl}{40}}$$

Substituting for P the evenly distributed load per $m^2 = p$, we have

$$P = pl$$

or

$$t = \sqrt{\frac{pl^2}{40}}$$

$$t = l\sqrt{\frac{p}{40}} \;\ldots\ldots\ldots\ldots (3)$$

If the plate has a concentrated load, say, in the center of the plate, we have, if this load is Q,

$$M_{max} = \frac{1}{4} Q\,l$$

however,

$$t = \sqrt{\frac{Q\,l}{2000}}$$

or with l in meter,

$$t = \sqrt{\frac{Q\,l}{20}} \;\ldots\ldots\ldots\ldots (4)$$

The dimensions of carrying rods are, according to formula (2),

$$F_b = t$$

If the number of rods is n, and area of each rod in $cm.^2$ is f, we have

$$f = \frac{F_b}{n}$$

and for f in $mm.^2$, which comes easier

$$f = 100\frac{F_b}{n} = \frac{100\,t}{n}$$

If each rod has a diameter *d*, we have

$$\frac{\pi d^2}{4} = \frac{100\ t}{n}$$

$$d = \sqrt{127.3 \frac{t}{n}} \text{ millimeter} \qquad \ldots\ldots\ldots\ldots (5)$$

For instance, if an apartment building has I beams 1.5 m. on centers and an even load of 500 kg. per m., we have

$$t = l \sqrt{\frac{p}{40}} = 5.3 \text{ cm., say, } n = 10$$

$$d = \sqrt{127.3 \frac{t}{n}} = 8.2 \text{ mm.}$$

If $n = 15$, we have $\quad d = 6.7$ mm.

Monier Arches.

(A.) If the form of the arch is *parabola*, and it is evenly loaded the line of strains is a parabola and the rods are only exposed to compression. If h is the height of the arch in meter, and using the same denominations as before, we have, according to Mr. Koenen:

p = pressure in kg per m²

$$t = \frac{pl}{2} \frac{\sqrt{1 + \frac{l^2}{16\ h^2}}}{k + \frac{1}{m}(K-k)} \text{ in millimeter}$$

And $F_b = \frac{100}{m} t$, where m is a coefficient varying between 20 and 100 and F_b in mm² for $b = 1$ m. If $\frac{l}{h} = 10$, which is most usual, we have

$$t = 1.35\ pl \frac{1}{k + \frac{1}{m}(K-k)} \qquad \ldots\ldots\ldots\ldots (1)$$

and when

$$f = \frac{F}{n} = \frac{100\ t}{nm}$$

$$d = \sqrt{\frac{400\ t}{\pi nm}} = \sqrt{127.3\ \frac{t}{nm}} \qquad \ldots\ldots\ldots\ldots (2)$$

For instance: $\quad l = 10$ m. $\quad p = 500$ kg. $\quad m = 30. \quad n = 10.$

$$t = 1.35 \times 500.10 \frac{1}{30 + \frac{1}{30}(750-30)} = 125 \text{ mm}$$

and

$$d = \sqrt{127.3 \frac{125}{10.30}} = 7.28 \text{ mm}$$

(B.) If the form of the arch is a *circle* with a rise of $\frac{1}{10}$ of the span, we have

$$t = \frac{pl}{k}\left(0.617 + \sqrt{0.38 + \frac{1}{117}\,\frac{k}{p}}\right) \dots\dots\dots\dots (1)$$

and
$$d = \sqrt{\frac{4}{\pi}\,\frac{t}{n}} = \sqrt{1.273\,\frac{t}{n}} \dots\dots\dots\dots (2)$$

t and *d* being expressed in *mm.*

Monier Pipes.

(A.) For cylindrical pipes with internal pressure, Mr. Koenen gives the following formula:

$$t = \frac{pr}{k + \frac{1}{m}(K - k)}$$

Where $2r$ is internal diameter of pipe.
p pressure per unit against inside of pipe.
t thickness of pipe.
k tension capacity of cement $= 3$ kg. per cm.^{2}
K tension capacity wrt. iron, 750 kg. per cm.^{2}
$\frac{1}{m}$ a coefficient varying between $\frac{1}{20} - \frac{1}{100}$
Length of pipe = the unit.

(B.) For cylindrical pipes with external pressure, the same formula is applicable, but by substitution of new values for *k* and K:

$$k = 30 \text{ kg. per cm.}^2$$
$$K = 750 \text{ kg. per cm.}^2$$

Reservoirs and Tanks.

Mr. Koenen gives for circular tanks the following formula, when the tanks are to contain liquids (Fig. 2):

$$t = \frac{A\,x\,t}{k + \frac{1}{m}(K - k)} \dots\dots\dots\dots (1)$$

Where *r* is internal radius, A specific gravity of liquid, *k* and K, tension strains for cement and iron as before,

$$t_h = \frac{A\,h\,r}{k + \frac{1}{m}(K - k)} \dots\dots\dots\dots (2)$$

For h=o, we get t_0=o, but for practical reasons a section is chosen near the top of tank, which can most easily be made.

The foregoing shows the general method of calculating Monier constructions, but, of course, as circumstances alter cases, the engineer naturally would make his own formulæ to conform to the

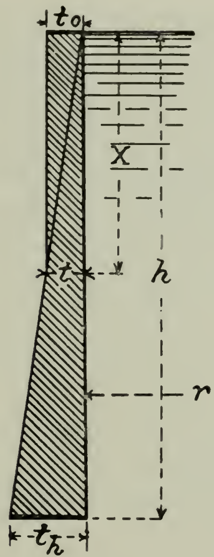


FIG. 2.

conditions in each instance. As an example, I will mention the calculation of grain tanks where the weight of the contents does not act as a liquid, but where the greater part of the load is transmitted to the walls as a vertical component. Here the engineer must make his formulæ according to his own experience and experiments, as the coefficient $\frac{1}{m}$ changes with the relation between diameter and height of tank, the kind of grain to be stored, etc. If any one cares to examine into the deductions of M. Koenen's formulæ, I would advise him to obtain the "Centralblatt der deutschen Bauverwaltung," of the year 1886, published in Berlin.

WRITTEN DISCUSSION.

Mr. H. P. Boardman—Without professing to know much about this subject, I should like to bring up one or two questions for the sake of getting information. Referring to Fig. 1, page 333, and the discussion relating thereto:

The assumption is made that the concrete takes all the compression and the steel all the tension. It seems to me that, whatever assumptions are made, the concrete will take some tension. Supposing the correct ratio between compression and tension in concrete to be 10, would it not be correct to assume that the concrete in the lower half of the plate or beam takes 1-10 of the tension, and embeds only sufficient steel to take the other 9-10 of the tension?

But the most puzzling question to me is, where is the neutral axis or neutral surface of this composite beam? Is it correct to assume that it will remain at the geometrical center of the section when you inclose another substance unsymmetrically in it?

Again, what method is used to determine the relation between the unit stresses of the steel and concrete?

Assuming the two substances as concentrated equidistant from and on opposite sides of the neutral surface, it seems to me that their relative unit stresses should be taken in the ratio of their moduli of elasticity, i. e., since $E = \frac{f}{\lambda}$ or $\lambda = \frac{f}{E}$, and the distortion of the two substances should be equal or $\lambda_1 = \lambda_2$, $\frac{f_1}{E_1} = \frac{f_2}{E_2}$ or $\frac{f_1}{f_2} = \frac{E_1}{E_2}$.

Where E = modulus of elasticity
f = the unit stress
λ = distortion in a unit length.
and sub $_1$ applies to concrete,
and sub $_2$ applies to steel.

Assuming $E_2 = 30{,}000{,}000$ and $E_1 = 2{,}000{,}000$, this gives $\frac{f_1}{f_2} = \frac{1}{15}$

But in the case in hand, neglecting the tension of the concrete as the author does, and assuming the neutral surface to remain at the center, the distortion at T must equal the distortion at S and, since f_1 should equal the maximum fibre stress or that of the upper fibres of the beam, the fiber stress corresponding to the surface at $T = \frac{2}{3} f_1$ for which the distortion is λ_1. Therefore, since $\lambda_1 = \lambda_2$, $\frac{\frac{2}{3} f_1}{f_2} = \frac{E_1}{E_2} = \frac{1}{15}$, hence $\frac{f_1}{f_2} = \frac{1}{10}$.

Now, if f_2 is taken at 10,000 pounds that would make $f_1 = 1{,}000$ pounds, which seems, and doubtless is, much too high. Likewise, if f_1 is taken at 400 pounds that would make $f_2 = 4{,}000$ pounds, which seems much too low.

It seems to me that where the ratio between f_1 and f_2 is $\frac{1}{25}$ as given near the bottom of page 333 where $k = 30$ kg and $K = 750$ kg, the result will be that the neutral surface will move up or away from the steel rods.

ORAL DISCUSSION.

Mr. Heidenreich — I stated on page 332 that calculations of Monier plates are based upon leaving the mortar to assume the entire compression and the carrying rods the entire tension strains. This is merely so assumed to obtain a practical basis for the calculation. We give the Monier plates a thickness based upon the compression strength of the mortar, and then calculate the steel

rods in the due proportion given by the difference between little k and capital K. Mr. Boardman's objections are, of course, correct theoretically; but it is pretty hard to find any difference between results of the two calculations when it comes to inches or even millimeters. The matter has been very carefully gone into by Mr. Koenen, in his "Centralblatt der Deutschen Bauverwaltung," in 1886, and I would recommend Mr. Boardman to read that paper. It is interesting, but it is exceedingly theoretical.

I would add that Mr. Thatcher, in his paper on steel concrete construction, September 21, 1899, refers to the same relation between the strength of mortar, or concrete mixture, and steel, and refers to the moving or displacement of the neutral axis, or rather the center of gravity, of the combination.

Mr. Boardman—In regard to the displacement of the neutral axis; if that axis were moved up, would not that tend to increase the distortion of the bottom flange or bottom fibers? That, I should think., would tend to pull apart the concrete at the bottom, and yet, in practice I don't suppose it does, when worked out according to these formulæ.

Mr. Heidenreich—The iron or steel rods which are calculated to take the tension strength off the bottom of the beam or plate are made sufficiently strong to take the entire tension. If they do take the entire tension, there will be no perceptible strain on the concrete or the mortar, that I can see.

Mr. Boardman—If they take any stress at all, there must be some distortion, and since the cement or concrete surrounding those rods clings to them tightly, then it must be distorted with the rods to a certain extent; but as long as it does not pass the elastic limit of the concrete it would not break. But the point I tried to make was that it seemed to me that the rods, in getting a higher unit stress in proportion to their modulus of elasticity than the concrete does, would tend to displace the neutral axis—that is, I should think it would tend to make the rods stretch more than the concrete in the upper part of the beam compresses, and therefore it seems to me the neutral axis must actually move from its central position.

Mr. Heidenreich—Well, that tendency we have to take care of by means of a factor of safety. There must not be enough stretching of tension members to influence the concrete or the mortar.

The Chair—What do you assume is the elasticity, or the elastic limit, of concrete mortar or of cement mortar?

Mr. Heidenreich—I am not prepared to state. The modulus of elasticity depends entirely upon the mixture and ranges from 1,400,000 pounds to 6,000,000 pounds.

XCVIII

THE CONDITION OF WATER AND POWER DEVELOPMENT IN SOUTHERN CALIFORNIA.

By L. K. Sherman, M. W. S. E.

Read Sept. 19, 1900.

Southern California has experienced an unprecedented period of drought. The mean annual rainfall, in the valleys of the Santa Ana and San Gabriel, is about 18 inches. During the past three years the annual rainfall has been only 5 to 8 inches.

In the writer's recent visit, this country was seen in its least favored condition. Irrigation is the great necessity. With water, this perfect climate and fertile soil bears a luxuriant growth of almost all the products of the temperate and tropical zones. Without water, in the eyes of a tenderfoot, the country is a desert.

The construction of irrigation systems and water power plant has been carried to an extent so as to utilize almost all of the dry weather run-off. The storage systems have not been so completely developed, but there are several large reservoirs—the Hemet, Sweetwater and Bear Valley reservoirs, with masonry dams; the Cuyamanca, of earth, and the San Fernando submerged dam. There are several projects, proposed and under way, for dam construction, especially in the line of submerged dams for intercepting sub-surface streams.

The development of land is synonymous with the storage and distribution of water. A large part of the land under cultivation was made available by the numerous land and irrigation companies. The amount of water necessary for irrigation varies greatly according to the kind of crop, soil and amount of rainfall. All measurements of water are in California miner's inches (50 miner's inches equal one second foot). One inch of water, on an average, will irrigate eight or ten acres. The duty of water in Southern California is larger than elsewhere, as the scarcity of water has compelled careful and economical methods in irrigation.

The value of irrigated land runs from $40 to $150 per acre. Water is sometimes included with sale of land, and again is sold separately. In the latter case, the annual charge is about $15.00 per miner's inch, or say $1.50 to $2.00 per acre irrigated.

The companies operating water power plants for electric transmission are generally separate concerns from the irrigation com-

panies. The power companies are compelled to utilize the natural flow of the stream, so as not to interfere with irrigation rights. Water rights are jealously guarded, and are a cause of frequent litigation.

The practice in power development and irrigation head works can be illustrated by a description of some of the typical plants in operation. The power house of the San Gabriel Electric Company is located near Azusa, at the foot of the San Gabriel mountains. From it come the weirs for distributing the water, after it has left the wheels, to the flumes and ditches of various irrigators. The electrical equipment consists of four 300 K. W. Westinghouse generators. The current from the machine, at 500 volts, passes through transformers and is conducted, at a line voltage of 15,000, to Los Angeles, distant 23 miles. Here the sub-station receives the current in step-down transformers and four rotary converters, and delivers the current for local power and lighting. In connection with the sub-station is an auxiliary steam plant, which is used as the demand for current exceeds the available water power. Oil is used for fuel under the boilers. This is general practice and will be considered later on. Mr. A. C. Balch is chief engineer of the San Gabriel Company, and is prominent in the development of electric power transmission in the west.

The hydraulic equipment consists of four sets of Tutthill wheels, two wheels being placed on the same shaft with each generator. The wheels are of the impulse type, and receive the jet of water on buckets, placed alternately right and left on the rim of the wheel, and inclined a little outward. The jet of water is not split during the interval it acts on a bucket. The wheels are controlled by Tutthill and Lombard governors. The governor moves a blade which cuts the jet at the discharge nozzle and reduces the flow.

The general method of conducting water to the wheel in nearly all the power plants is as follows: The line consists of two parts. First, the flume which leads the water from its source in the mountain stream, spring or reservoir in the upper part of the canon. This part of the line is on an easy grade, from 5 feet to 25 feet per mile. It follows closely the contour lines on the side of the mountain and delivers the water in a small forebay, 300 feet to 1,000 feet above the power house at the mouth of the canon. Second, the penstock, a riveted steel pipe which conducts the water from the forebay to the wheels, down the hill at an angle of perhaps 45 degrees.

The economical location of a line for water power development offers problems that are not excelled in the most difficult railroad work.

The types of construction used for the hydraulic line are:

1. Open wood box flume.
2. Wood or steel pipe.
3. Tunnel.

In practice, combinations are used in the same line, as best suits conditions.

The accompanying views of flumes and pipe lines are not all taken in Southern California, but are given as they illustrate typical construction throughout the west. Fig. 1 is a view of a placer mining flume now in construction at Twin Lakes, Colo. Fig. 2 is a wood stave pipe carrying water for irrigation near Redlands, California.

Fig. 2.

The cost of the hydraulic line will be given for a few actual cases. However, these figures by themselves do not mean much, as numerous local conditions must be taken into account:

Cost of tunnel in San Bernardino Mts.,	5 x 7 ft.,	$8.00	per foot.
" " " " San Gabriel "	5 x 6 ft.,	3.50	" cubic yd.
" " 48 in. wood pipe near Redlands, Cal......		2.08	" foot.
" " 6 ft. diameter wood pipe............		6.00	" "

The flume at Twin Lakes, Colo., (Fig. 1) cost 20 cents per foot for carpenter work, including posts cut on ground. The total cost of the hydraulic line at Ogden, Utah, was about $700,000. There

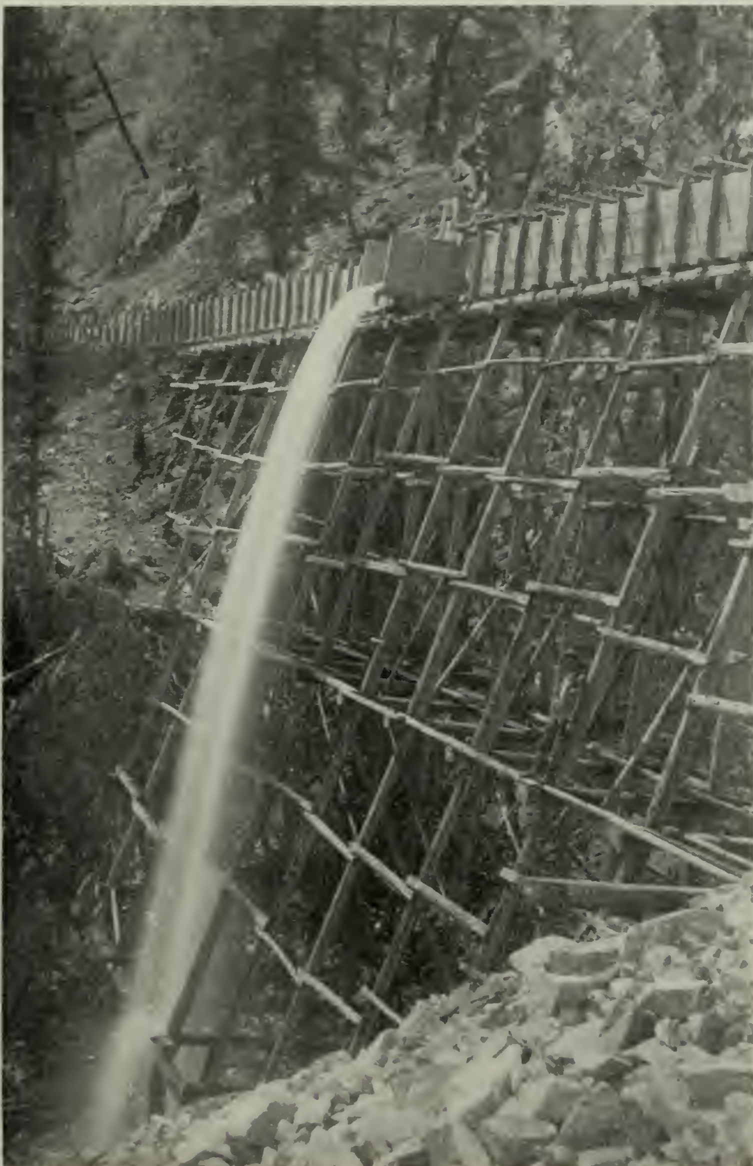


Fig. 1.

are $6\frac{1}{2}$ miles of wood pipe, 6 feet in diameter, and about 1 mile of 6 feet diameter steel pipe.

The San Gabriel Electric Company's hydraulic line conducts the

water in wood stave pipe and cement lined tunnels. The average grade is 5 feet per mile. Water is delivered to the wheels, previously described, under a head of 390 feet through a 36 inch riveted steel penstock.

In southern California one enters the canons from a plane, from which the mountains rise quite abruptly. There is no evidence of water but the past action in the river bed. The floor of the canon is a hot dry waste of sand and boulders, with no sign of vegetation, except coarse brush and cactus. But as one travels four or five miles further up, he will come across a thick growth of willows and sycamores, from which a small stream of water trickles, but it is soon lost as it sinks into the gravel. The somewhat paradoxical condition of a stream increasing in size as it nears its source appears.

Submerged dams are built across the canon to intercept this subsurface flow, to store it and raise the water to a higher level. A submerged dam is now being built by Mr. A. P. Newman, chief engineer for the San Gabriel Co. The trench is 6 feet wide, excavated through gravel by sheet piling. The depth to bed rock is from thirty to sixty feet. After completion of excavation the dam is to be made by filling the trench with concrete. The pit is pumped by electric current from the power station.

The Southern California Power Co. holds the world's record for long distance electric transmission and high voltage. The power house is located in the canon of the Santa Ana river, near Redlands, Cal. There are four 750 K. W. General Electric Co. generators, each operated by a direct connected Pelton water wheel under 735 feet head. Originally, an air chamber was attached to the penstock for an equalizer, but this has been abandoned. The pulsations set up by the compressed air added to, instead of remedying, the trouble. A deflecting nozzle is used, operated by a Lombard governor. This moves the nozzle, throwing the jet of water more or less on to the wheel as required. Power is transmitted to Los Angeles, a distance of 83 miles, at the high voltage of 33,000. The engineer, Mr. Pearson, informs us that they have had little trouble with the line, and that it is perfectly successful even in rainy weather. Both the San Gabriel and Southern California plants represent the latest and best engineering in electrical transmission. They are in a successful condition financially. The hydraulic line is about three miles long. It is almost entirely tunnel work. There is one section of wood flume, but it is proposed to replace this with tunnel to avoid falling rocks and land slides, a trouble that is of common occurrence on all the mountain side flumes. Fig. 3 shows the entrance to tunnel at the head gates.

At the time of the writer's visit, August, 1900, the electric plant at Sonora had just shut down, and both the San Gabriel and South-

ern California water plants were running at one-fourth capacity, due to lack of water. The auxiliary steam plants were run to make up the deficiency.

A proposed dam for a storage reservoir, at the junction of the Santa Ana and Bear Creek forms the outlet of the Bear Valley reservoir, which is fifteen miles above. The reservoir is reached by a drive over the San Bernardino mountains. The scenery on the road is grand. The trail, however, is as steep as a team can hold on to, and in passing it is sometimes necessary to unhitch, or to even take a wagon apart and carry it. The dam which makes the Bear Valley reservoir is well known, as its stabil-

Fig. 3.

ity depends almost entirely on its action as a masonry arch. The boldness of its design is somewhat startling. It is four feet thick on top and has a very little batter on the up stream side. The reservoir was entirely empty. This does not mean that it is a failure or has not served a useful purpose.

Recently, on account of the lack of water in many of the mountain streams and reservoirs, irrigation from artesian wells has been resorted to. Artesian wells have proven very successful. They are sunk from 200 feet to 400 feet. Sometimes there is a surface flow, but generally pumping over a small lift is needed to raise the water to the irrigating ditches.

Gas engines with centrifugal pumps are used. They are very

common. The "bark" of the gas engine can be heard now on almost any ranch in southern California. There are many types and arrangements of gas engines. One outfit, placed on a sprinkling cart of a suburban road, consisted of a small gas engine and rotary pump. The outfit did not weigh over 200 pounds and filled the cart from irrigation wells.

The fuel used in gas engines is distillate, a product from the California oil wells, that corresponds somewhat to gasoline. Distillate costs 8 cents or 9 cents per gallon. Coal is almost unknown. Crude oil is used under the steam boilers. Its cost for power is equal to coal at about $5.50 per ton.

Water pumped from wells is not quite as cheap as water furnished by the irrigation companies, when the latter can be secured. But pumping may be considered as a dry period auxiliary to irrigation, just as the steam engine is to water power. The great success of artesian wells has proven a salvation. I have not disguised the fact that water is expensive and difficult to secure. I wish to say, however, that although there has been no rain since last April, there are few places where the orchards show any effects of drought, and the cities of southern California present an appearance of permanent and substantial growth.

XCIX.

PROPOSED SPECIFICATIONS FOR STEEL RAILROAD BRIDGES.

By J. W. Schaub, C. E.

Read October 3, 1900.

Theory and practice both tell us that a moving load on any structure produces a more destructive effect than a fixed load. The action of the moving load, as distinguished from the fixed load, is an inertia effect, and the work done in overcoming this inertia must be absorbed by the various members of that structure, excepting that which is absorbed by the springs on the vehicles.

In a railway bridge the total load may vary from the sum of the fixed and moving loads, when the train is moving at a slow speed, to some approximation of the sum of the fixed load and twice the moving load when the speed is such that the weight of the train may be taken as falling freely to the extent of the deflection of the structure as a whole. The experiments (Transactions American Society of Civil Engineers, Vol. XLI, page 410) made in 1897 by Prof. F. E. Turneaure, show that the effect of speed alone is of no practical importance, unless it be for very short spans, say 40 feet long, and this conclusion is warranted by the deductions from theory alone. In addition to this inertia effect, commonly called impact, there are vibrations produced, owing to the unbalanced mechanism of the locomotive, and imperfections in the track and wheels. The experiments made by Prof. Turneaure show that speeds greater than 20 miles per hour for short spans, and 35 miles per hour for long spans, invariably cause large vibrations. In general, the vibration increases with the speed, but not as rapidly as the square of the speed, as the theory of centrifugal force would suggest. Moreover, any imperfections in the design of the bridge itself may be shown by increased vibrations, both vertically and horizontally. This was brought to my attention very forcibly in the case of a bridge with floor beams having hangers eccentrically loaded, a defect which was remedied by introducing equalizing hangers, thereby doing away with the eccentric loading, and at the same time reducing the vibrations very perceptibly. In another case, a bridge having wooden stringers which were overloaded to the extent that they deflected abnormally, the effect of a moving load at high speeds, produced excessive cumulative vibra-

tions. In this case, the addition of another stringer under each rail caused these excessive vibrations to disappear.

The experiments made by Prof. Turneaure show that these imperfections in the design of a bridge, and all designs are imperfect, produce secondary stresses which are far greater than those produced by impact and vibration. By means of an extensometer he measured the stress in the bottom outside flange of a girder 25 feet long, to be 180 per cent of the computed value, whereas the bottom inside flange showed a stress 45 per cent of the computed value.

All of the effects of a moving load can then be provided for, as though it were a purely fixed load, if we allow a proper percentage for impact and vibration. This percentage can then be added to the sum of the fixed and moving loads and the whole treated as a fixed load.

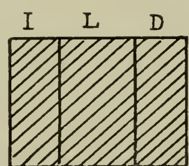
In any member of a bridge, the total effective area of the cross section is used in overcoming the total effect of the fixed and moving loads.

Let D denote fixed load.

Let L denote moving load.

Let I denote impact and vibration.

Then D+L+I can be represented by the area of the cross-section of that member, as per sketch.



Area of section = D+L+I. What relation shall "I" bear to "L"? In other words, what impact shall be provided for? If we provide a proper percentage for impact, and proportion the member so that the resulting stress shall never approach the elastic limit, no fatigue of the metal will result, and the celebrated experiments made by Wöhler rather confirm this view, than justify any provision for fatigue. In other words, if the resulting stress will never approach the elastic limit, the metal is not susceptible to fatigue, and consequently the load can be applied an indefinite number of times.

Then ignoring the Launhardt formula, which is based on Wöhler's experiments, as inapplicable to bridge design, a common practice has been to provide for impact by making I = L, that is, allowing 100 per cent for impact and vibration for all lengths of spans.

This does not seem rational, and the experiments made by Prof. Turneaure and presented to the American Society of Civil Engineers December 7, 1898, do not justify such an assumption.

These experiments show that the increase in deflection due to impact and vibration, caused by locomotives running at high speed, varies with the length of the span, being likely 40 or 50 per cent for spans less than 50 feet in length and decreasing rapidly for longer spans.

Neglecting the effect of the springs on the vehicles, the action of the moving load sets into vibration not only the fixed load but the moving load as well; and, inasmuch as the inertia effect of the moving load is the direct cause of the impact and vibration, it follows, from this reasoning, that the ratio of the moving load to the total load in any member must be a measure of the effect produced. Would it, then, not be more rational to make the ratio between I and L dependent upon the ratio between the moving load and the total load, or

$$\frac{I}{L} = \frac{L}{L+D} - C \ldots\ldots\ldots\ldots (1)$$

in which "C" is a measure of the effect produced by the springs on the vehicles in overcoming the vibrations due to high speeds. The value of "C" is intended to cover everything that absorbs the impact and vibrations of the moving load, excepting the member under consideration. The observations made by Prof. Turneaure show that for very short spans the effect of impact combined with secondary stresses produced a stress which was 180 per cent of the computed value, or $\frac{I}{L}$ was 0.80. In equation (1) for very short spans we can make D O; then equation (1) becomes

$$\frac{I}{L} = 1 - C = 0.80 \therefore C = 0.20$$

making "C" equal to zero, in very short spans; in equation (1) we then have for vehicles without springs,

$$\frac{I}{L} = \frac{L}{L+D} - O \therefore I = L \times \frac{L}{L+D} \ldots\ldots\ldots\ldots (2)$$

When D=O, we have I=L, or for all moving load I=100 per cent of L.

When L=O, we have I=O, or for all fixed load no allowance is made for impact. This formula was first proposed by Mr. H. S. Prichard, engineer, New Jersey Steel & Iron Company, in 1895, and seems to have been entirely overlooked until the same formula was again proposed by Mr. E. H. Stone in his paper on the "Determination of the Safe Working Stresses for Railway Bridges,"

(Transactions American Society Civil Engineers, Vol. XLI, page 486). To be sure, Mr. Stone recommends another formula, in lieu of the above, but the experiments made in this country are more in accord with the formula proposed by Mr. Prichard.

Having provided for impact and vibration, we can then provide for the sum of D, L and I as though the whole were a fixed load. Assuming a metal with an elastic limit of not less than 30,000 pounds per square inch, and allowing a margin of 100 per cent for safety within the limits of elasticity, the proper unit stress to allow would be 15,000 pounds per square inch, both for tension and compression, the latter to be reduced by introducing the same in a proper column formula. By this method of proportioning, a constant unit stress is used for all members, the value of "I" providing for all the effects of the moving load in every part of the structure down to a single rivet.

With the value of "I" obtained from equation (2), I have computed the impact values in percentage of the moving load for the bottom chords of truss spans up to 400 feet long, using the "E—40" loading of Cooper's Specifications, 1896. These values are shown on the diagram, Fig. 1. I have also plotted, on the same diagram, the maximum observed percentage of increase in deflection due to speeds from 40 to 50 miles per hour, from the experiments made by Prof. Turneaure. The lower curve on the diagram shows the computed values for impact in percentage of moving load, from equation (1) allowing 55 per cent for impact absorbed by the springs, or

$$\frac{I}{L} = \frac{L}{L+D} - 0.55$$

To be sure, the curve does not follow the plotted values very closely, owing, no doubt, to the varying conditions under which all experiments of this kind must be made. The value of "C" was taken at 55 per cent, so as to make the value of $\frac{I}{L} = 0.45$ for very short spans when "D" can be taken equal to zero. In other words, Prof. Turneaure has shown that for very short spans, for high speeds, the impact is about 45 per cent of the moving load, and it is here assumed that if the vehicles had no springs the impact would be 100 per cent of the moving load, so that 55 per cent must be absorbed by the springs on the vehicles.

On the same diagram, Fig. 1, I have plotted the impact values given by Cooper's Specifications, and the specifications of the Michigan Central R. R., and the St. Louis & San Francisco R. R. The latter are the same specifications proposed by Henry B. Seaman.

FIG. I.

(Transactions of the American Society of Civil Engineers, Vol. XLI, page 140.)

The impact values given by Cooper's Specifications are 100 per cent for all lengths of spans. This makes the short spans too light when compared with the long spans. This same criticism applies to all specifications in which the impact values are not made to vary with the length of the span. The impact values given by the specifications of the St. Louis & San Francisco Railroad and

the Michigan Central Railroad are made to vary with the length of the span in spans up to 100 feet long. For spans over 100 feet the impact value is the same for all lengths of spans. If the effects of the impact are known to exist in all spans, and as the experiments show that it is a maximum for spans less than 50 feet long and to decrease rapidly for longer spans, it should be made to vary by some rational formula and the values of "I" given by equation (2) seem to meet the results of the experiments made by Prof. Turneaure better than any yet proposed.

The question might be asked, Would it not be just as well to make the value of "I" vary with the length of the span covered by the moving load? This, I understand, is now the practice of the Pennsylvania Railroad, and also that of several prominent bridge engineers in this country. This gives rational results for the chord members, but for web members near the center of the span, special values must be used. Moreover, for bridges with heavy ballast floors the same impact would be added to the moving load as for bridges with ordinary timber floors, which is not rational. The percentage for impact, or the value of $\frac{I}{L}$, should be dependent upon the ratio of the moving load to the total load, as previously shown.

In the present state of information regarding impact, it must not be supposed that any one formula can be made to cover the widely varying conditions under which we find impact to exist. For example, taking one element of impact alone, such as the counterweights in the drivers of the locomotive. A particular engine on one span may produce excessive cumulative vibrations, whereas the same engine in another span of the same length, but with different panel lengths, may produce no cumulative vibrations at all. So that the question of impact is a complex problem, indeed, and the only thing to do, in the present state of our knowledge, is to adopt some rational method in proportioning our bridges, and the method proposed is certainly rational and entirely on the side of safety.

Based on the impact formula given by equation (2), which was first proposed by Mr. H. S. Prichard, in 1895, I have prepared a specification for steel railroad bridges which I beg to submit to the members of your Society, with the view that it may bring forth a discussion. (See Appendix "A.")

In order to save time I will only touch upon such features in these specifications which are different from the usual requirements.

Paragraph 11 has a clause which specifies the minimum moving load, which is to be used in proportioning, at 1,000 pounds per

lineal foot. This, of course, is to be combined with a wind load at 30 pounds per square foot, blowing horizontally, to obtain the maximum overturning moment in high bridges. This train load, of 1,000 pounds per lineal foot, is just able to withstand a horizontal wind pressure of 30 pounds per square foot without overturning the cars, so that as long as the cars remain on the track they can be considered as a part of the total area exposed to the wind.

The same paragraph provides for an impact in movable bridges, while in motion only. This must not be understood to mean that movable bridges can have a moving load on them while in motion. This impact is made a part of the fixed load, and is only another way of providing a lower unit stress for the fixed load while in motion. The impact for the riveted connections of the floor system is made 125 per cent of the moving load. This is made large in order to take care of all contingencies which may arise, such as eccentric connections, tension on rivet heads, etc. For all other members the value of "I" is made dependent upon the ratio of the moving load to the total load, as previously explained by equation (2).

Paragraph 13 provides for a maximum wind load of 30 pounds per square foot, acting on all exposed surfaces, whereas the usual requirements are 50 pounds per square foot, when no train is on the bridge. The experiments made on Mount Washington in 1890, and the observations on the effects of the St. Louis tornado by Mr. Baier (Transactions American Society of Civil Engineers, Vol. XXXVII, page 285,) show that a pressure of 30 pounds per square foot is ample, and with a unit stress of only one-half the elastic limit this wind pressure could be doubled with safety. In this connection, I would like to say that the Washington University in St. Louis has fitted up a means of measuring the actual wind pressure in terms of the velocity, and Professor Nipher has informed me that as soon as the wind blows he will be able to give us the information we are all looking for, and which has never been supplied.

Paragraph 14 provides for tension and compression at 15,000 pounds per square inch. As long as we confine ourselves to within the limits of elasticity, there is no reason why any difference should be made between tension and compression. To be sure, the latter value should be reduced by some column formula, and the formula here proposed is the Rankine-Bouscaren formula, with the 18,000 in the denominator changed to 15,000. This change is made in order to discourage the use of slender columns. No distinction is made between square ends and pin ends, and one formula is intended to cover all conditions. The tests so far made on bridge members have been made in a testing machine, and it is

a question if we are justified in assuming that the same conditions obtain in a bridge as in a testing machine. In order to be on the safe side, it is better to make all light members with riveted connections and then treat them as though they were pin connected.

Paragraph 14 also provides for the shear on machine driven rivets at 12,500 pounds per square inch. This forms the basis of the subsequent values given for tension and bearing, and was arrived at by assuming the elastic limit for rivet steel at 27,500 pounds per square inch, and using one-half this value, reduced by 10 per cent for shear. Within the limits of elasticity there is no reason why the shear cannot be taken at the same value as for tension. The bearing on rollers is given by the formula 500 x "D" per lineal inch, in which "D" is the diameter of the rollers. This is according to the formula proposed by Professor C. Bach, P = K x D, in which "K" was taken, for steel rollers on a steel track, at 500 pounds per lineal inch. The value of "K" given by Professor Bach, for the same conditions, is 851 pounds per lineal inch.

The values given for timber apply to the cross-ties and any timber used for wall plates. These values were obtained from the timber tests made at the Washington University in St. Louis, in 1892, by Professor J. B. Johnson, for the Department of Agriculture, U. S. Government. The fibre stress due to bending is based on the cross-breaking strength of yellow pine at 8,000 pounds per square inch, which is sufficiently low to cover all grades of yellow pine. The value to be used in proportioning for fixed loads is taken at one-fourth of 8,000 pounds, or 2,000 pounds per square inch. This makes the relation between the working value and the ultimate strength for wood the same as for steel. White oak is taken at the same value as yellow pine.

White pine and hemlock are taken at two-thirds the value given for yellow pine and white oak, according to the relative values given for white and yellow pine by the tests previously mentioned.

The values for bearing are taken at one-half the crushing strength across the grain per square inch, which is certainly permissible for fixed loads.

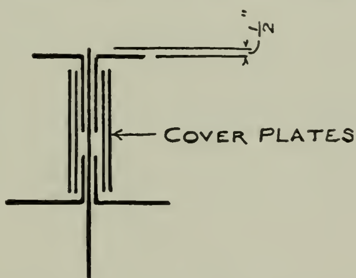
Timber for wall plates is now used in short spans to relieve the masonry from shocks and eccentric loading, and proves very serviceable for this purpose. A clause is added to the values given for bearing on timber, so that in no case shall the bearing come near the end of a stick.

Paragraph 15 recognizes that fatigue in steel can occur when a reversal of stress approaches within the elastic limit, according to the experiments made by Professor Bauschinger (Föppel's Technische Mechanik), so that alternate stresses of tension and

compression are provided for separately, and the required sections are added in determining the total sectional area.

Paragraph 16 provides that rolled and built beams to resist bending shall be proportioned by the moment of inertia of their cross-section. If we allow for any holes cut in the web, or reinforce the same properly, it is certainly good practice to consider the web in proportioning any beam. Moreover, it encourages the use of thick web plates without stiffeners, rather than thin web plates with stiffeners.

Paragraph 17 excludes deck plate girders with the cover plates on the top, and specifies that they shall be put on the sides of the



top flange, as per sketch. This is to avoid the dapping of cross-ties and boring the ends for rivet heads, and makes one cross-tie just like the other. This is a great advantage to the bridge carpenter when any ties have to be renewed, or it becomes necessary to bunch the ties in order to get down through the floor. Moreover, the dapping weakens the cross-ties and should be abolished. With this form of top flange the lateral bracing can be kept free from the cross-ties by attaching the same to the lower angles, and thereby doing away with the trouble from loose rivets in the bracing, owing to the deflection of the cross-ties.

Paragraph 18 provides for intermediate stiffeners according to the maximum shear at any point in the web, by the well known Gordon formula in which the numerator is made 18,000 pounds. In using this formula it is assumed that the web of any girder under consideration is divided up into lengths each equal to the depth of the girder, when each imaginary section is treated as a column in which "H" is the ratio of the depth of web to its thickness. The term shear on the web is used only to convey the idea that there is a vertical load on each imaginary section of the web, and the intensity of this load is assumed as uniformly distributed on the horizontal area of each section. Now, as long as each section is imagined to be as long as the web is deep, this horizontal load must be just equal to the vertical shear on the web at that point. In case it is found that each web section can carry the shear as a column, no inter-

mediate stiffeners are required. In no other instance is the so-called shear on the web of a girder recognized, for if we accept the definition of a shear as the effect of a sliding between two contiguous surfaces, such a thing as shear on the web of a girder cannot exist, and all of the tests ever made on rolled and built beams show that they fail by the buckling or tearing of the webs on diagonal lines, or owing to insufficient rivet bearing at the ends, excepting, of course, such failures as are due to weak flanges.

The stiffener formula, herein proposed, provides for intermediate stiffeners to carry the algebraic sum of the loads, or shear, at any point. Now, it can be shown that if we can in some way get the load into the web, that no stiffeners will be required whatever, excepting, of course, the end stiffeners. This is contrary to all of our accepted theories of web stresses, but a little experiment can be made to demonstrate this.

Make a plate girder model out of drawing paper, about 15 inches long and 3 inches deep, with two flange angles top and bottom, and let the web of the girder project below the bottom flange angles so that the loads can be suspended by means of hangers attached to the projecting web. Now support the girder on the ends and support the top flange against crippling sideways. We will find that loads can be suspended from the hangers with perfect safety that cannot be placed on top of the girder without buckling the web. Moreover, the web will stiffen up at once, and we will find that although the web is already carrying the suspended loads we can now place additional loads on top of the girder and the web will not buckle. It follows, then, that after we get the load into the web, the web is actually stiffer than it was before, so that stiffeners need only be provided to get the load into the web and not to carry the maximum shear at any point. Would it then, not be more rational to proportion our intermediate stiffeners to carry only the maximum concentrated load at any point, rather than the maximum shear?

If we adopt this method of proportioning, we will find that very small angles will suffice to carry the vertical loads into the web, and it was thought perhaps better to adhere to the former methods to avoid the use of small intermediate stiffeners. However, there is no question, that for through plate girders we need provide for intermediate stiffeners only to attach the floor system to the web, and that between the floor beams, or panel points, no intermediate stiffeners are required, no matter how long the panels are, or how thin the web may be; but for practical reasons, it is best to put in the intermediate stiffeners to take out any buckles or initial stresses which may exist in the web.

Clause 20 specifies that the neutral axis in any compression

member, shall coincide with the center of the cross-section as near as practicable. This is to prohibit the use of unsymmetrical sections; that is, sections which are not balanced about the center line of the cross-section. Placing the pin in the neutral axis of an unsymmetrical section does not distribute the load uniformly over the entire section, but produces bending in addition to the direct load.

Clause 25 specifies that all holes in the flanges of rolled beams shall be drilled. This is to prohibit the punching of holes in the flanges of rolled beams used as stringers, so as to avoid the torture to the metal necessary in punching through metal having a surface which is not at right angles to the punch, and results in distorted holes on the under side of the flange.

Clause 31 provides that the borings for chemical tests shall be taken from the pulling or bending test pieces, and not from the ingot, bloom or slab. This is to establish a closer relationship between the physical and chemical tests. The usual practice, in taking the borings from the ingot, is open to criticism, in that the borings can be taken so as to avoid segregations of impurities where they are known to exist in the ingot.

Clause 34 specifies the paint to be used to be made of lamp black and boiled linseed oil. To this should be added a little litharge or the mon-oxide of lead to secure a hard surface to the paint.

Theoretically red lead is the ideal paint, but it is expensive and requires too much skill to properly apply it. Red lead as used on work for the Canadian Pacific Railway in 1884 was very satisfactory, and the secret of it was that the paint was mixed with japan to make it dry quickly and avoid the streaking or running of the wet paint. This, I believe, has been the principal objection to the use of red lead, aside from the extra cost.

In order to compare the results obtained in using the proposed specification with some standard specification, I have prepared a diagram, Fig. 2 [see next page], which shows the percentage of increase in sections of the bottom chords of spans up to 400 feet long, as compared with Cooper's Specifications, E-40 loading. Neglecting the webs in both cases, the stringer flanges for 25 foot panels are 23.2 per cent heavier, the floor beams 19.3 per cent heavier, and the corresponding suspenders 13.6 per cent heavier. If the web is considered in the stringers, for the proposed specification, this difference disappears; that is, the web in the one case just offsets the increase in the flanges required. For truss spans 100 feet long the increase in bottom chord sections is found to be 8 per cent. For longer spans it becomes less, being only 1 per cent for spans 400 feet long.

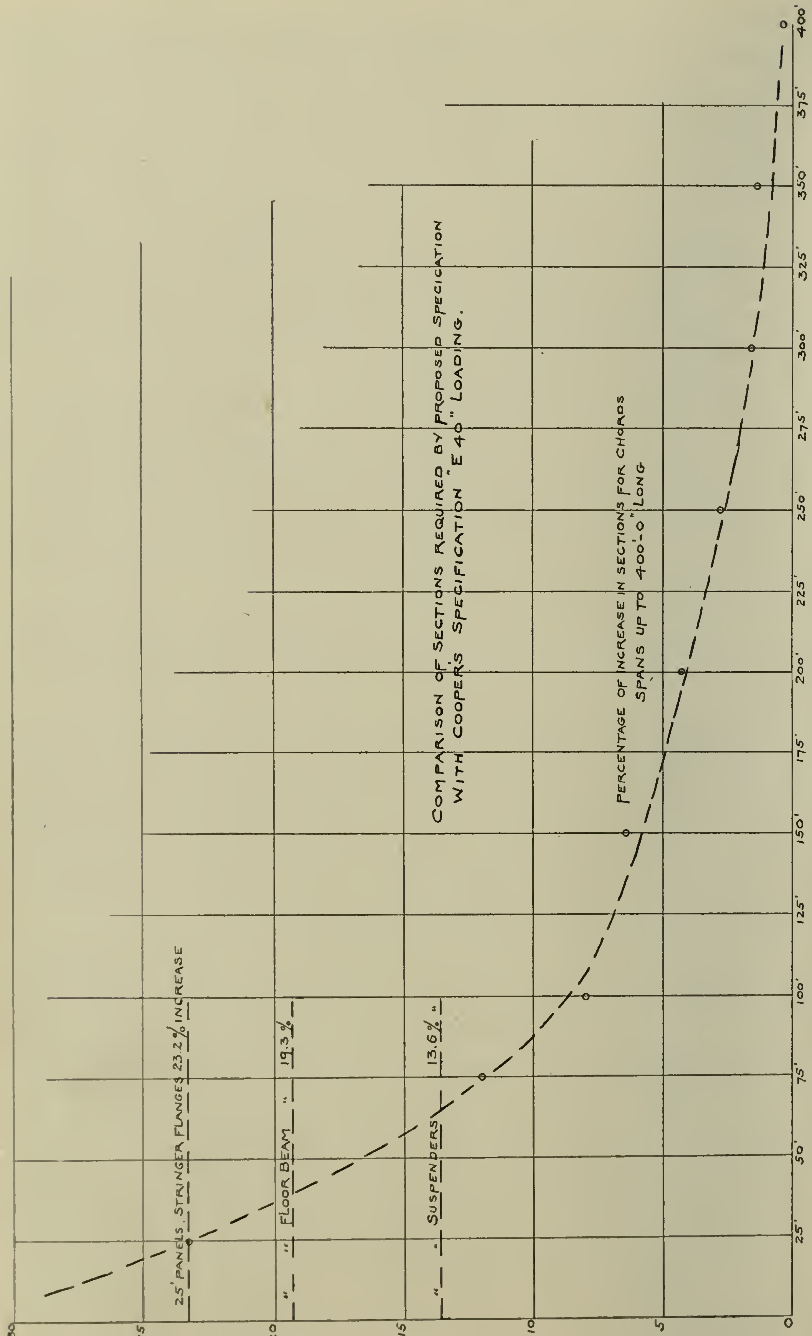

Comparison of sections required by proposed specication with Cooper's specification "E 40" loading.
Percentage of increase in sections for chords spans up to 400'-0" long
25' panels. Stringer flanges 23.2% increase
" " Floor beam " 19.3% "
" " Suspenders 13.6% "
0
5
10
15
20
25
30
25'
50'
75'
100'
125'
150'
175'
200'
225'
250'
275'
300'
325'
350'
375'
400'

Fig. 2.

The methods herein proposed are advocated because they meet our present ideas of the effects of impact and provide for them in a rational and intelligent manner. Using the values for impact, obtained by equation (2), which makes no allowance for the effects of the springs on the vehicles, is certainly rational and entirely on the side of safety. At some future time when we know more about the effects of impact, we can perhaps use a better formula, but, in the meantime, we should proportion our bridges for impact by some such methods as herein proposed.

Moreover, existing structures which are too light to carry present loads at high speed can be intelligently analyzed, and the exact margin for impact found. For example, in an iron bridge recently examined, I found the material in the main trusses strained up to 15,000 pounds per square inch with no allowance for impact. The natural conclusion is that this bridge is perfectly safe at slow speeds, say, not to exceed 15 miles per hour. In another case the margin found for impact was about one-half that given by the formula, so that a greater speed is permissible.

APPENDIX "A."

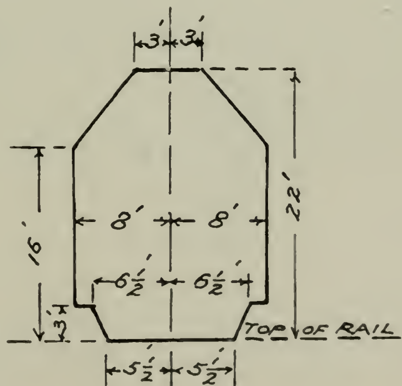
SPECIFICATIONS FOR STEEL BRIDGES.

GENERAL REQUIREMENTS.

1. Riveted plate girders or rolled beams shall be used for spans less than 90 feet, and for deck spans shall be spaced 7′ 0″ center to center.

Truss spans with riveted connections shall be used between 90 and 130 feet, and pin connections for spans above 130 feet.

2. The clear opening on a straight track shall be according to diagram. Two or more tracks will be spaced 14′ 0′, center to center.



On curves the clearances shall be increased at all points 2 inches for each degree of curvature.

Trusses generally shall be spaced about 1-15 the length of the span, apart, but not less than 14 feet c. to c. of trusses, for deck spans.

3. All connections of the floor system and wind bracing shall be riveted.

All bracing shall preferably be stiff bracing; that is, capable of resisting both tension and compression.

Deck spans generally will have no bottom wind bracing, the wind load being carried to the top by means of suitable transverse bracing.

4. All details, workmanship and materials shall be first-class, and in accordance with the best modern practice.

5. Before material is ordered, a complete bill of material shall be furnished the engineer of the railway company, and approved by him, and two copies for all orders for material must be sent to him at the time the orders are sent to the mills. Sub-contracts for material must not be given to contractors objected to by the engineer.

6. Contractors when submitting proposals shall furnish drawings showing stresses and sections for all members, and such detail drawings as are necessary to show the mode of construction.

Before work is commenced in the shop, two complete sets of all detail drawings shall be furnished the engineer, and approved by him. One of these sets shall be made on linen.

7. Before work is commenced at the shop or mill, notice shall be sent to the engineer sufficiently in advance to enable him to send an inspector for the work.

8. The stipulation as to time of completion shall be strictly complied with, unless an extension of time is granted by the chief or bridge engineer in writing.

9. The decision of the engineer shall control as to the interpretation of drawings and specifications during the execution of the work thereunder; but this shall not deprive the contractor of his right to redress, after the completion of the work, for an improper decision.

PROPORTIONING.

The bridge shall be proportioned to resist the following loads:

10. *Fixed Load.*—The weight of the bridge itself, including the floor. If a ballast floor is to be used, the same shall be assumed to weigh —— pounds per lineal foot for each track. If a timber floor is to be used, the same shall be assumed to weigh —— pounds per lineal foot for each track.

11. *Moving Load.*—A train on each track, as shown in the following diagram. [See opposite page.]

When the track is curved, the speed of the train shall be assumed at 90 feet per second.

For a minimum moving load on the bridge, assume a train weighing 1,000 pounds per lineal foot.

In order to provide for impact and vibration, an amount is to be added to the above loads, in each member, according to the following formulas:

D=Fixed load.

L=Moving load, including centrifugal force.

I=Amount to be added for impact and vibration.

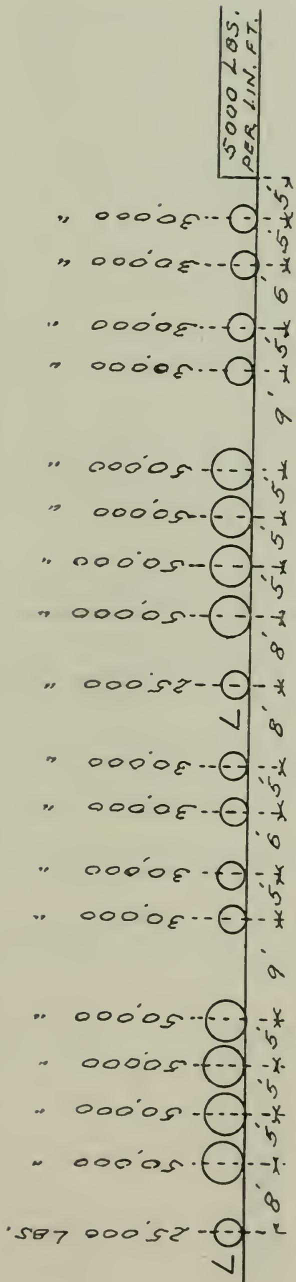
For movable bridges, while in motion only, $I=0.25\times D$.

For floor beam hangers and the riveted connections of the floor system, $I=1.25\times L$.

For all other members, $I=L\times\dfrac{L}{L+D}$

12. *Friction.*—For longitudinal force, the coefficient of friction between the wheels and the rails shall be 0.20.

13. *Wind Load.*—A wind pressure acting in any direction on all exposed surfaces with a force of 30 pounds per square foot when the bridge is unloaded, or 30 pounds per square foot when the train is on the bridge, the train being assumed to be 10 feet high and to commence 3 feet above the top of the rail. This load,



DIAGRAM—MOVING LOAD. (SEE CLAUSE 11).

when it comes on any member carrying a moving load, need not be considered unless it exceeds $\frac{1}{3}$ of the moving load (including centrifugal force, but without impact), when only such excess need be provided for. When, however, the longitudinal force due to friction exceeds the total wind load in any member, the latter can be entirely neglected. For truss spans, the wind shall be assumed as acting on both trusses. For girders, the wind shall be assumed as acting on one girder only, including the surface of the floor and track, when exposed to the wind.

14. In proportioning any member the greatest possible combination of the above loads shall be provided for, as follows :

Tension at 15,000 pounds per square inch, net.

Compression at $$\frac{15000}{1 + \dfrac{L^2}{15000 \times R^2}}$$

in which L = length of member in inches.

in which R = least radius of gyration in inches.

in which $\frac{L}{R}$ must be less than 120.

Shear on rivets and pins at 12,500 pounds per square inch.

Tension on rivets and pins at 12,500 pounds per square inch.

Bearing on rivets and pins at 25,000 pounds per square inch.

When riveting is done by hand, the number of rivets shall be increased by one-fourth.

Bending on pins, extreme fibers, at 25,000 pounds per square inch.

Bearing on rollers at $500 \times D$ per lineal inch, in which "D" is the diameter of the rollers, and must not be less than 3 inches.

Bearing on masonry at 400 pounds per square inch.

Bearing on timber at 250 pounds per square inch for white pine and hemlock, and at 400 pounds per square inch for yellow pine and white oak.

In no case, however, shall the bearing on the timber come near the end of the stick.

Fiber stress on timber, due to bending, at 1,333 pounds per square inch for white pine and hemlock, and 2,000 pounds per square inch for yellow pine and white oak.

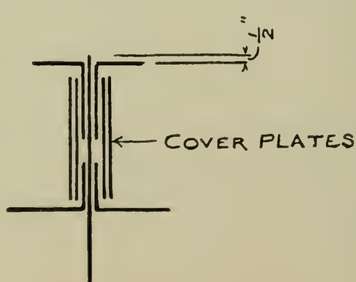
Temperature stresses shall be provided for a change in temperature of 150 degrees Fah.

15. Members subject to alternate stresses of tension and compression shall be so proportioned that the total sectional area is equal to the sum of the areas required for each stress.

16. Rolled and built beams to resist bending shall be proportioned by the moment of inertia of the cross section, care being taken in built beams that the web plates are properly spliced at the joints and properly reinforced at the stiffeners.

DETAILS.

17. Deck plate girders shall have no cover plates on the top, but on the sides, as per sketch.



18. Intermediate stiffeners shall be providedfor as struts carrying the maximum shear at any point, including impact, whenever the shear per square inch of the web exceeds

$$\frac{18{,}000}{1 + \frac{H^2}{3{,}000}}$$

in which "H" = ratio of depth of web to its thickness; and they shall be spaced at intervals of about the depth of the girder.

19. No metal shall be less than ⅜ inch thick, excepting that used for fillers and lattice bars.

20. Compression members shall be so proportioned that the neutral axis coincides with the center of the cross section, as near as practicable. The unsupported width of any plate subject to compression shall not exceed 30 times its thickness, excepting cover plates for chords and end posts, which shall not exceed 40 times their thickness.

21. All open sides of compression members shall be stayed by latticing and tie plates at each end.

The tie plates shall be as near as possible to the ends, and not shorter than the width or depth of the member.

For members having a depth of 10 inches or less, the size of the lattice bars shall vary between 1¾ x 5-16 inches for 6 inch channels and 2 x ⅜ inches for 10 inch channels.

For members 12 to 20 inches deep, the lattice bars shall have 2 rivets in each end, and be 4 inches wide for ¾ inch rivets, and 4½ inches wide for ⅞ inch rivets. Their thickness shall vary between 5-16 for 12 inch channels and ½ inch for 20 inch channels.

For members over 20 inches deep, 3 x 2 x ⅜ angles shall be used.

No lattice bar or tie plate, however, shall have a thickness less than 1-50 the distance between rivets connecting it to the compression member.

In all cases the distance between connections of lattice bars shall not exceed 35 times the least radius of gyration of the sections connected by them.

22. All holes for field rivets, excepting those for wind bracing, shall be drilled or reamed from an iron template.

23. Ends of floor beams and floor girders shall be faced.

24. All parts which have been partially heated shall be annealed.

25. All punched holes, excepting those in the bracing, shall be reamed 3-16 inch larger than the diameter of the die used in punching the hole. Generally the die shall not exceed the diameter of the punch by 1-16 inch. All holes in flanges of rolled beams shall be drilled.

26. The compression flanges of beams and girders shall have the same gross section as the tension flanges,and must not have an unsupported length greater than 15 times their width.

QUALITY OF MATERIAL.

27. Cast iron or steel may be used for the gearing of movable bridges and for bed plates. Rolled or hammered steel and rivet steel shall be used for all other parts.

28. Rolled or hammered steel shall be made by the open hearth process and shall contain not more than 0.06 per cent of phosphorus.

It shall have an ultimate strength of 60,000 to 68,000 pounds per square inch, with an elastic limit of not less than one-half the ultimate strength.

The elongation shall not be less than 22 per cent in 8 inches. It shall bend cold under a hammer, until the sides of the test piece are in contact throughout, excepting at the bend where the opening between the sides may be not greater than the thickness of the test piece.

29. Rivet steel shall be made by the open hearth process and shall contain not more than 0.04 per cent of phosphorus. It shall have an ultimate strength of 50,000 to 58,000 pounds per square inch, with an elastic limit of not less than 55 per cent of the ultimate strength, with an elongation of not less than 25 per cent in 8 inches. It shall bend cold under a hammer, until the sides of the test piece are in contact throughout.

30. All steel when punched in the ordinary manner, two diameters from the

edge, shall stand drifting to a diameter $\frac{1}{3}$ greater than the original holes, without cracking either in the holes or on the edges of the piece.

31. The physical and chemical tests shall be covered by three tests of each kind for each cast, and each group shall be taken from different furnace heats if practicable. The pulling and bending pieces shall be cut from the finished plain material, side by side. The borings for the chemical tests shall be taken from the pulling or bending pieces, and not from the ingot, bloom or slab.

32. Steel castings will be used for swing bridge rollers, track segments and gearing, unless iron castings are specified. When tested they must show an ultimate strength of not less than 65,000 pounds per square inch, with an elastic limit of not less than one-half the ultimate strength, and an elongation of not less than 10 per cent in 2 inches.

33. Cast iron, except where chilled faces are specified, shall be tough gray iron, free from blow holes. Sample pieces, one square inch in section, shall be capable of sustaining on a clear span of 4 feet 6 inches a central load of 500 pounds, when tested in the rough bar as it comes from the sand.

PAINTING.

34. All recesses which will retain water, or through which water can enter, must be caulked or filled with some waterproof cement. All work before leaving the shop shall be scraped clean by means of wire brushes, and be given one good coating of boiled linseed oil. All finished surfaces shall be coated with white lead and tallow.

In riveted work the surfaces coming in contact shall be given a coat of paint. Parts inaccessible after erection shall be given two coats of paint. The paint to be used shall be made of lamp black mixed with boiled linseed oil.

After the bridge is erected, the metal work shall receive two additional coats of lamp black mixed with boiled linseed oil.

WRITTEN DISCUSSION.

Mr. Horace E. Horton—It goes without saying, that we are all wanting to design structures in the most rational way for the work said structures have to endure.

Mr. Schaub chooses to propose the application of two variables to each span, while it is obvious that variables may be combined with a saving of labor in computation.

Take the proposed loading and the increase for impact—the variable being the varying dead load of the structure, due to length of span—and it happens that, if we assume 150 per cent greater loads—that is, maximum axle load of 125,000 pounds and equivalent loads for other parts and use 20,000 pounds unit stress instead of 15,000 pounds, we will have developed the same structures, member for member, for any span from 10 to 400 feet, that the proposed impact addition will develop, with this very desirable addition, that the counters are increased; and as we may expect a very material increase in the weight of the loads in due time, the method here suggested fully provides for counter stress when the loads shall have increased 150 per cent. The unit stresses will be excessive, but no more than many structures are worked to at the present time.

We have heard statements from year to year, that the limiting load on bridges had been reached.

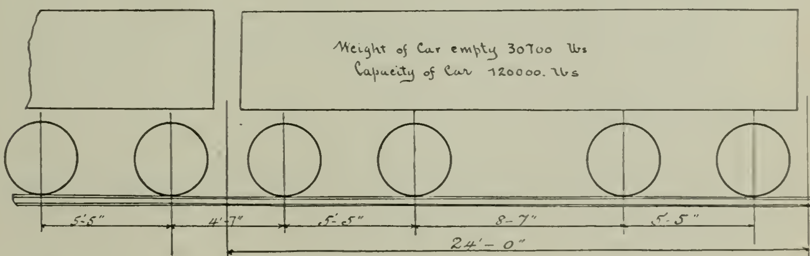
We know of 225,000 pounds carried on drivers of a locomotive, this engine successfully running on rails not more than one and one-half times as heavy as rails in use when maximum engine loads on drivers were no more than 100,000 pounds.

This shows us that the weight of the engine is increasing more rapidly than the weight of the rails, and there is no limit in sight as to size of rails.

The power of the locomotive is directly as the size of the boiler, and boilers are scarcely more than 45 per cent of the cross section possible with the present gauge.

Judging the future by the past, we have every reason to expect loads of 100,000 pounds on one axle, with several axles to the engine, within the next few years on trunk lines, as the usual practice; hence, I believe it entirely out of place to attempt to suggest any strength at which it is desirable to proportion bridges.

Not only engines, but the cars and the loads are increasing. My attention is called to cars when loaded weighing 6,250 pounds per lineal foot of track (see diagram); while the engine proposed



by Mr. Schaub weighs 6,052 pounds per lineal foot of track, followed by cars of 5,000 pounds per foot.

Our specifications for bridges were written in 1878, twenty-two years ago. The structures today are three times as strong as the standard at that time, and at all times new structures have been designed and built, varying in strength all the way as one to two.

I speak of these examples merely to establish my proposition, that there is no use of attempting to name the limit of strength for structures either for the present or the future.

The class of traffic, the condition of the treasury, and the atmosphere surrounding the enterprise, must be the basis upon which to arrive at a rational structure.

No fast and sure rule for loads can be set out, with any hope of its being followed.

Referring to the general requirements of the specification, we

all admit that the "American practice" of bridge building is being materially modified. Plate girders and riveted connections are much more in favor, and pin-connected work less so. Now, if it is accepted that riveted connections are equally, or more, desirable than pin connections, is there any reason, other than a commercial one, that we should say at what length of span pin-connected work should be introduced.

I am disposed to assert that the economical length of plate girders, as compared with open trusses, in riveted work, will vary materially as between the through and deck spans; hence, I see no reason to arbitrarily say that spans under 90 feet long shall be plate girders, while spans of greater length shall be open trusses with riveted connection, if less than 130 foot span, and pin connection if of longer span. My own observation leads me to conclude that through spans should never be built as plate girders for more than a moderate length, while plate girders may be profitably employed for deck spans of nearly or quite double the length than for through ones.

Why shall we propose to space tracks of the railroads fourteen feet, center to center, while thirteen is the standard?

Why shall we increase the width of the bridge, on straight lines, from fourteen feet, the standard of all the years that have passed, to sixteen as suggested?

In fact, the whole first nine paragraphs of the specifications are merely suggestions of personal preference, with no good and sufficient reason why any of them may not be varied materially without modifying the integrity of the structure.

The whole of our experimental knowledge of fatigue and strength of materials, justifies using the same unit stress in tension as compression; compression being modified as per length of member. I would make the lower divisor in the formula, $10{,}000 \times R^2$, and leave out any further limitations.

I approve, emphatically, the author's assumption that compressive members in a structure like a bridge are of two pin end character. If we bethink ourselves of the conditions in a bridge, it is apparent that they are entirely different from those in the testing machine. The testing machine is self contained, and in its action on one member gives fixed support from the very nature of the case; while in the bridge the same force which tends to deflect one member will also tend to deflect those that have been assumed to furnish fixed support for the member under investigation.

I would make the unit stress for shear of rivets, pins and girder webs, etc., three-fourths tension; and I would make the bearing on rivets and pins, and also the exterior fiber stress on pins, one and one-half times tension.

These relations to tension are essentially conventional; and slight variations serve no useful purpose, but cause an unlimited amount of nuisance in a manufacturer's office.

Two hundred and fifty pounds per square inch is the usual practice for bearing on masonry, and if it is used instead of 400 pounds, as proposed in the specification we are discussing, there would be less occasion to put a cushion between the structure and the masonry.

I protest against the indiscriminate demands for material for both tension and compression in a member that has possible alternating stress, excepting as the demand is qualified by the probabilities of the case.

In the light weight members at the center of a span, where the alternetic stresses actually occur, undoubtedly some attention should be paid to the claim that such stresses are more destructive than stresses acting in only one direction; however, if we properly assume (and our experience justified the assumption) that the bridge under any circumstances will be in service only twenty years, 135 trains crossing a day would, in such time, produce one million reversals—a number that laboratory experiments on small samples may have shown to be more destructive than direct stress by some small per cent.

The specification written in 1878, specified that, in built beams, bending stresses should be carried by the flanges and shear by the web, and as a result we see, here in the city of Chicago, that of four distinct designs of elevated railroad work by noted engineers, all have spliced, for shear only, the webs of girders at center of span, making use of about 80 per cent of the strength of material in their hands; that is, in the structures, strong enough as they are, there is 20 per cent more material in them than there should be. It is a bit of irony that the only elevated road in this city, in which the web is arranged to take bending strains, with splices made away from the center of the girder, should have been designed by the same individual that wrote the specification of 1878, which evidently other designers have read, and have followed like sheep without any reason for such act.

It is not only so with the elevated railroads; in fact, it is so with the girders commonly and generally in use throughout the country. A large per cent of material has been tossed absolutely in the air by the designers. It is an exception to find a girder designed to take advantage of the web to carry bending stresses. The proposal to complete girders by the moment of inertia is undoubtedly fully justified by the conditions.

As to the details in the proposed specification in the matter of

the top flanges of girders, angles may be used for a top flange, leaving out the side plates; four will make a top flange that has all the desirable qualities suggested, and but few of the objections. If 8 x 8 x 1 1/8 inch angles are used a considerable span may be built. (See photograph.) In this case two 8 x 8 inch angles will furnish as much section as the four angles and two plates used. The center of gravity of the top flange would be more than 5 inches higher, with added stability in proportion. I cannot help feeling that the design suggested may with propriety be omitted.

I regret that the clause bearing on reaming is in such uncertain terms that I cannot tell whether the work is to be reamed or not. It says: "Except in the bracing;" and as the bracing is such a considerable proportion of a structure, I am at a loss to judge whether reaming is to be done by a punch or reamer.

I cannot neglect the opportunity to speak of the specification as to lacing. It is my understanding that lacing is to be used so that paint may be applied to the inside of the compressive member. To accomplish this, the openings through the lacing must be large enough for a workman to freely use his arm on the inside—that is, the openings must be at least 4 x 4 inches. If it happens, as it frequently may, with a member built of, say, 10 inch channels with the flanges turned in, that the gauge lines of the rivets securing the lattice will not be over 6½ inches apart, then the panels and the lattice must be longer than the usual 60 degree relation, or else the very purpose of using the lattice is ignored. Again, if we are

building 10 inch channels, and there is occasion to put them, say, 24 inches back to back, flanges turned out, the panels of the lattice will be too long if at 60 degrees. Again, as to the lattice itself, it should be thicker as to its width, due to its length, the width being governed by the size of rivets being used in the member.

A rational specification for the size and spacing of lattice for the varying conditions as they come up in practice cannot be based on a certain size of lattice for a given size of channel only. The relation to make a consistent design is complex.

As to the size of rivets, shop practice seems to have developed the diameter of rivet to be equal to ¼ the width of the flange or angle. This may be varied somewhat; that is, you may use a ⅞ inch rivet in a 3 inch angle or flange of channel on occasion, but a ¾ inch rivet fits a 3 inch angle or flange more satisfactorily. If we are using 2½ inch angles or channels with 2½ inch flanges, ⅝ inch rivets would serve more satisfactorily than ¾ inch.

I have noticed a disposition to over-rivet the material, both as to the size of the rivets and the number used.

As to the quality of material, it is very well understood at this time that rolled steel shapes, plates and bars can be had to certain standard specifications. If a person chooses to write a specification that is less severe in its demands than the standard one, there is no difficulty in getting material to it, on the theory that the greater or better always includes the less or poorer. For rolled steel there is no occasion to write specifications, because you can get no better material than the standard specification specifies.

ORAL DISCUSSION.

Mr. J. W. Schaub—I only want to say in regard to Mr. Horton's criticisms, with which I generally agree, that there are conditions over which I have no control. Sixteen feet clearance has been adopted by numerous railroads; the Michigan Central requires sixteen feet; the Chicago & Alton requires sixteen feet; and the railroad company for which this specification was prepared requires sixteen feet.

When you add the impact formula to the fixed and moving loads and allow the pressure on the masonry at 400 pounds per square inch, you get almost identically the same result as when you allow the pressure on the masonry at 250 pounds without impact. You must bear in mind that every unit is increased by that impact formula even if it is a unit on the masonry. The results over here, that I have on this other side of the board [referring to the blackboard], happen to be the reactions on the masonry for a 128 foot

deck span with a 40 foot approach span at each end. Taking the bearing value on the masonry at 400 pounds per square inch, requires 1,320 square inches in bearing; whereas, by the usual method of proportioning, without impact, we allow 250 pounds per square inch, which would require 1,352 square inches in bearing.

Mr. Ralph Modjeski—I read Mr. Schaub's paper with great interest, and have prepared a few scattered notes on those paragraphs of his specification which most attract my attention.

Paragraph 2. The spacing of the tracks 14 feet centers seems to me excessive. Thirteen feet is the standard spacing on many railroads and 12 feet 6 inches on some. I think 13 feet gives ample room between cars and a greater distance results in that much additional cost on account of the corresponding spread in the trusses or girders.

It is further stipulated that the minimum distance from center to center of trusses of deck spans shall be 14 feet. I think this also excessive. For deck spans from 130 feet to 160 feet I generally make this distance 12 feet and increase it by 6 inches for every increase of 10 feet above 160 up to 200 feet.

In paragraph 3 Mr. Schaub dispenses with bottom lateral bracing in deck spans. This is right. Such bracing is superfluous.

With regard to paragraph 8, concerning the time of completion, I am in favor of specifying a small penalty for each day of delay, a penalty which the engineer may waive if he so chooses, but which certainly acts as an incentive for completing the work on time. In fact, the stipulations as to time and penalty should be embodied in the contract rather than in the specifications.

Paragraph 9 of Mr. Schaub's specifications contains this sentence: "But this shall not deprive the contractor of his right to redress, after the completion of the work, for an improper decision."

This paragraph is the same as the standard manufacturers' specifications for workmanship, paragraph 11. It is quite natural that the manufacturers would wish some such clause put in, but, from an engineer's standpoint, I ask who is to decide whether the decision was proper or not?

In paragraph 11 Mr. Schaub proposes to use one type of, or rather one typical, engine. Each road has a maximum type of engine of its own, sometimes several types used on various branches. The weights of these typical engines vary considerably. We are far from tending to adopt one type, or even an approximately similar type, of locomotive for all the railroads, and that is because the conditions of traffic, grades and operating are so different in

each case. The adoption of one type of loading would therefore result in excessively heavy bridge work in one case and too light in another. I believe, therefore, that the loading should be divided into classes, whether typical diagrams or uniform loads are used. In each individual case the conditions should be studied and suitable loading adopted.

I fully agree with Mr. Schaub that Launhardt's formula is inapplicable to bridges. In the first place, the loads are not applied frequently nor rapidly enough, and in the second place, the stresses never approach the elastic limit in correctly designed work. As a matter of curiosity I have reduced the Wöhler and Launhardt formulæ to the following form:

$$\frac{\frac{D}{2}+L}{S} < E \qquad (1)$$

where D is total minimum load with its algebraic sign, L the range of stress, S the section, and E the elastic limit per unit of section. When no reversals occur, D is the dead load and L is the live load.

As long as this condition is satisfied, no fatigue of metal is possible. Taking the elastic limit at 30,000 pounds per square inch and S = 1 square inch, we have

$$\frac{D}{2} + L < 30{,}000 \qquad (2)$$

Should $\frac{D}{2} + L$ be equal to 30,000, the fatigue of metal *might* begin and, if so, it would take several millions of applications of the load before the material fails. Within the range of usual stresses to which a well designed structure is submitted the number of applications of the load to produce a break could be considered as infinite, no matter what the relation is between dead and live, or minima and maxima, loads.

It might be interesting to remark that, substituting 10,000 for the elastic limit in formula (2), we obtain the usual formula for proportioning steel tension members where the dead load weight is 20,000 pounds per square inch or twice the live load limit.

I consider Mr. Pritchard's and Mr. Schaub's formulæ as very practical and covering the conditions as well as our present knowledge of the subject permits it. As to the uniform strain of 15,000 pounds which is multiplied by the various coefficients, I would be inclined to think that it is somewhat low. It is quite easy to obtain metal of from 62,000 to 70,000 pounds ultimate, with 36,000 pounds minimum, elastic limit. These limits were, on my suggestion, adopted by the Northern Pacific Railway in their latest speci-

fications and I have had no difficulty in carrying them out without paying premium on the metal. Would it not be just as well, then, to take 18,000 pounds, or half of this elastic limit, and call for metal of corresponding quality? Or take, say, 16,000 pounds for punched work and 18,000 for reamed work? Any increase in this quantity is that much economy in the structure, and, therefore, any increase in the elastic limit, everything being equal, represents that much economy.

Paragraph 16. I fully agree with Mr. Schaub that all beams should be figured by the moment of inertia of the whole section, including the web.

I have figured the comparative sections in the middle panel of the bottom chord at various spans required by Mr. Schaub's formulæ and under my own specifications. I found that the excess given by Mr. Schaub's method is 11 per cent for spans of 130 to 180 feet and 10 per cent for spans of 180 to 200 feet, showing that Mr. Schaub's formulæ and mine only vary in what might be called the strain coefficient, which Mr. Schaub takes at 1,500 pounds. If that were changed to suit, the various sections required under both methods would be practically identical for that range of spans.

With regard to the specification for reaming. This, as Mr. Schaub gives it, is the usual specification; but I have found in my experience that we get better results by specifying that the holes for ⅞ rivets shall be punched 5-16 smaller instead of 3-16. What we wish to avoid by reaming is the distorted metal around the hole. Take, for instance, the bottom flange of a riveted girder; supposing one hole only is mispunched; even if all other holes are perfect, if that one hole happens to be in the center of the girder or near some point of maximum strain, the whole value of the reaming is gone. Therefore, if reaming is specified, one should be careful that all the holes are actually reamed out.

About the elastic limit: I see Mr. Schaub specifies one-half of the ultimate for the elastic limit. This is a very easy requirement to fill, and there is no trouble about obtaining steel in which the elastic limit will reach 60 per cent of the lower limit for ultimate strength. In metal ranging from 60,000 to 68,000 ultimate, I would call for an elastic limit of not less than 35,000 pounds per square inch.

With regard to stiffness: I have always considered that the stiffeners in through girders are not necessary except at the point of floor beam connection. I have used them to straighten the web or to take the buckles out of the web, more than to make them carry any load or transmit any shear.

Mr. T. L. Condron—Mr. Schaub's specification for reaming required that:

"All holes, excepting those in the bracing, shall be reamed 3-16 of an inch larger than the diameter of the die used in the punching of the hole. Generally, the die shall not exceed the diameter of the punch by (more than) 1-16 of an inch. All holes in flanges of rolled beams shall be drilled."

Mr. Modjeski has stated that, in his experience, he finds better results are secured by specifying that the holes for ⅞ inch rivets shall be reamed 5-16 of an inch instead of 3-16 of an inch. In the case of ⅞ inch rivets, the finished size of the hole would be 15-16 of an inch in diameter. According to Mr. Schaub, he would require that the punching for these holes be made with a 11-16 inch punch and a ¾ inch die, while, if I understand Mr. Modjeski, he recommends punching ⅛ of an inch smaller than this; that is, he would require a 9-16 inch punch and a ⅝ inch die, in order to secure 5-16 of an inch reaming. In the case of material more than 9-16 of an inch thick, the punch would be smaller in diameter than the thickness of the material, and for material over ¾ of an inch thick, this would increase the difficulty in punching, and injury to the material punched.

Some years ago I made a series of laboratory experiments of punching with different diameters of punches and varying thicknesses of material. The results of these experiments showed that the greater the clearance between the punch and the die the less force was required to punch the material, and that for thick material a greater clearance was required than for thin material. As the thickness of the material approached the diameter of the punch, it was found that not only was the force required to punch increased, but the apparent injury to the material was greater. Moreover, if the thickness of the material exceeded the diameter of the punch, I found considerable trouble in maintaining the punches, as they would crush or fail after making a few holes; but of more importance to the engineer was the fact that the evidences of injury to the material were very much more marked in cases where the punch was less in diameter than the thickness of the material, than in the case where the punch was greater than the thickness of the material. This led to the conclusion that there is a decided disadvantage in punching material over ¾ of an inch thick, or thicker, with 9-16 inch punches. Another point is, that the usual practice in the shop is to have punches varying by even eighths of inches, so that usually you find ⅝ inch, ¾ inch, ⅞ inch, etc., punches, with the dies from 1-16 to 3-32 of an inch larger than the punches they are to be used with.

With reference to the specifications governing the quality of material, I have taken the requirements for tensile tests and the

chemical analyses of 41 different specifications as tabulated in a report of the International Association for Testing Materials, and have compared with these the requirements suggested or recommended by the American branch of the committee on steel specifications of this association, this committee having issued a number of proposed standard specifications for rails, axles, structural steel, etc. Nearly all of the specifications referred to are railroad specifications.

Under the heading "Medium Steel," I find specifications calling for steel as low as 56,000 pounds ultimate strength, and as high as 70,000 pounds. Most of the specifications allow a range of but 8,000 pounds. The lower limits of tensile strength for medium steel in these specifications vary between 56,000 and 62,000 pounds, while the upper limits vary between 65,000 and 70,000 pounds.

The requirements for elastic limit of these several specifications are as follows: One-half ultimate strength, 54 per cent ultimate strength, 55 per cent ultimate strength, and 60 per cent ultimate strength; also, the elastic limit is frequently specified as not less than a given amount, as: 32,000, 33,000, 34,000, 35,000, 36,000, and 37,000 pounds. There is an equally great range in the requirements for minimum reduction of area, which varies from 36 per cent to 50 per cent, while the minimum elongation called for in 8 inches varies from 17 per cent to 25 per cent. The same comments can be made on the requirements for soft steel and rivet steel, and correspondingly great variations are specified with reference to phosphorus and sulphur. Some specifications limit the phosphorus in basic steel to three hundredths of one per cent, while others allow as high as eight hundredths of one per cent, and some again place no limit on the phosphorus. Likewise, the sulphur is limited by some specifications to two hundredths of one per cent, and others to ten hundredths of one per cent.

It should be appreciated that where but comparatively small quantities of material are being ordered by one purchaser, it is unreasonable for him to expect to secure steel differing materially from what is being ordered by others at the same time for similar uses. Where the demand for steel under any one specification is so large as practically to control the output of any one mill, it is possible to make a peculiar specification governing the same, and to secure almost any steel desired, provided the extra cost of the manufacture is paid for. But, in general, the best results would be obtained by adhering to uniform specifications for the same grades of material. The mills can then direct their energies toward the production of uniform material within standard specifications, and

purchasers can demand more strict adherence to such specifications.

I will not attempt, at this time, to discuss the specifications proposed by the committee of the International Association for Testing Materials, as it is my purpose to discuss them in detail at another time; but while referring to them, I may say a word regarding the range of 10,000 pounds ultimate tensile strength provided for in the proposed specifications, taking the case of medium steel as an illustration. Few engineers would raise any objection to the upper limit of 70,000 pounds, provided they felt assured that none of the material going into their structure would have a higher tensile strength, and correspondingly less ductility, than would be found in steel of 70,000 pounds ultimate strength; but the facts of the case are, that the tests made of steel in the mills can never represent all of the material intended to be covered by the tests. The usual specifications require a single tensile test from each heat of steel. So long as this test fulfills the requirements of the specifications, and the bend tests are successful, the entire heat of steel is considered acceptable for the class of material and gauge represented by one test. This raises the question as to how much variation in physical properties will be found in material of the same gauge made from one heat of steel. My observations lead me to the conclusion that this variation is always considerable, and it is not unreasonable to believe that fully 6,000 or 8,000 pounds' range of tensile strength must be expected. Now, if one test selected at random should show a tensile strength of 65,000 pounds, and it is the only test we have to base our opinion on for a given lot of material, it is reasonable to conclude that some of the material will be as much as 4,000 or 5,000 pounds above or below the showing of the test in tensile strength, and, in extreme cases, 8,000 or 10,000 pounds; that is, should the test be from material rolled from the bottom of an ingot and finished hot, showing the lowest tensile strength, another test of the steel from near the top of the same ingot, and finished cold, would probably give results differing as much as 6,000 or 8,000 pounds in tensile strength. If, then, the one test gave a tensile strength of 65,000 pounds, some of the steel from the heat represented by the one test would probably run either as high as 70,000 pounds or as low as 60,000 pounds tensile strength. If, now, the one test considered approached near to either the upper or lower limit, you would have to conclude, by the same process of reasoning, that some of the steel would be as much as 5,000 pounds or more, either above or below the limits of specification. It is manifestly impossible to determine, by the tests made, the physical properties of all of the steel used; and, therefore, the range of tensile strength should be quite limited for the usual

heat tests, and I, therefore, favor the narrower limit of 8,000 pounds for regular tests, where only one or two tests per heat are required, placing the upper limit for medium steel at 68,000 pounds instead of 70,000 pounds. I would further recommend that where the first test gives results not more than 4,000 pounds outside of the limits prescribed, one or two additional tests, selected by the inspector, be permitted, and if the average of the two or three tests falls within the specification, the material should be accepted; otherwise it should be rejected.

With the upper limit placed at 68,000 pounds, it might safely be concluded that none of the steel would, probably, exceed 73,000 pounds tensile strength; likewise, placing the lower limit at 60,000 pounds would give reasonable assurance that none of the steel accepted would run below 55,000 pounds.

These ranges may seem large, but I feel confident that they are not greater than the facts of the case warrant, and they do not affect the matter of design as seriously as might at a first glance appear, as every designer should keep his stresses well inside of the elastic limit of the material, and, in fact, the unit stresses adopted are generally considerably less than one-half of the elastic limit of steel of 55,000 pounds tensile strength. However, the strength of the material must be the underlying principle in designing, and it is equally as important that a correct understanding of this strength be had by the engineer, as that he shall accurately calculate the stresses imposed by loads on his structures.

Mr. Schaub—The requirements in the specification I mention are the standard Carnegie requirements. I don't understand your remark at all. They were copied from the standard spedifications of the manufacturers.

Mr. Condron—Not the latest edition.

Mr. Schaub—But they are principally the old requirements of the manufacturers, sixty to sixty-eight thousand; the elongation is 22. That is the same; the only difference is 2,000 pounds more in the manufacturers' range. That proposed specification is very modest, indeed.

Mr. Henry Goldmark—The various aspects presented by the subject of bridge specifications cover too large a field for detail discussions. I would like simply to say a word on the subject of material.

Steel has now been used for bridge work almost exclusively for about ten years. Excepting for a few very large bridges, of exceptional length of span, the ordinary grades of mild steel are perfectly satisfactory. The engineer in his tests will gain nothing by attempting to get steel different in a few slight particulars from the average product. In long span bridges, say over 2,000 feet in

length, there is a field for a harder steel, perhaps an alloy of nickel or some other expensive but very strong steel. In using this hard steel the workmanship should approximate closely to the best machine work, all edges being planed, and rivet and bolt holes drilled in the solid.

In the case of the ordinary mild steels the testing should have for its main object the securing of a uniform grade in all parts of the bridge. In the opinion of the speaker this means more particularly a uniform chemical and physical structure, rather than an absolute equality in the tensile strength of all the different members. At the present time a great majority of specifications prescribe the same tensile strength, elastic limit, elongation and reduction of area in the case of the very smallest bars or shapes and the heaviest plates or beams. Some of this metal is only ¼ inch thick and some of it 2½ and even 3 inches thick. And still the same 60 to 68 thousand pounds ultimate strength is prescribed. The result is that the manufacturer, to obtain the same tensile strength in the heavy sections as in the light ones, must use a much higher steel, i. e., a steel that has more carbon, and probably also more of the other hardeners. The result is that we get in these heavier sections a much less reliable steel—one that is more brittle and likely to be less homogeneous. It is true we prescribe a test for ductility and also a bending test. These are both valuable, but as the result of considerable experience I am satisfied that they are not sufficient to weed out unduly high steels. Some years ago I was connected with a large undertaking in which several thousand tons of large steel plates were used. They varied from ⅜ to ⅞ of an inch in thickness. The specification required exactly the same ultimate strength in all of them, viz.: 60 to 68 thousand pounds per square inch. These plates were carefully tested and complied fully with the specifications. They were all of them "rolled" into large cylinders after being punched for making necessary connections. While all these plates were undoubtedly safe, those above ⅝ in thickness were much more brittle and needed more careful handling to avoid injury in their manufacture.

From these and other experiences, I am satisfied that a very desirable reform would be the adoption of a sliding scale in the requirements for ultimate strength. The ultimate strength as well as the elastic limit should vary with the area of the different sections, the heavier ones having lower requirements. This would enable the manufacturer to use a steel of practically uniform composition and give us a safer material. I do not think there would be any objection to this course from the standpoint of the bridge designer, and hope that the committee of the International Asso-

ciation for Testing Materials will adopt this provision in their proposed standard specifications.

Mr. Schaub—In Mr. Horton's discussion he spoke about the equivalent uniform loading. I did not quite understand. If I remember aright, the equivalent load for that engine for a span of 50 feet was over 8,000 pounds per foot. The engine specified is the heaviest that is in existence, excepting one on the Pittsburg, Bessemer & Lake Erie. They have an engine there calling for 56,000 pounds on the axle, I believe, so that the load specified is certainly excessive and the results of the estimates show it. Spans figured by that specification figure about 13 per cent heavier than by the E 40 loading of Cooper's specifications.

Mr. Horton—With a car that weighs 6,250 pounds per running foot of track, undoubtedly it would be a matter of prudence. The particular car I refer to figures about 9,000 pounds per feet, equivalent radius on 10 foot panel. One of our Chicago roads has actually in service cars of a capacity of 120,000 pounds, weighing a trifle over 30,000 pounds. In making these statements I do not wish to be considered in any sense as being critical; I wish simply to illustrate the problem we are considering.

Mr. Schaub—Well, that is a remarkable car, because I thought the heaviest cars were the cars ordered recently for 110,000 capacity.

In regard to the punching which Mr. Condron spoke of, referring to the difficulty of getting straight holes, I found no difficulty whatever in getting straight holes, when they were drilled. The holes were perfectly clear and perfectly straight; it relieves the material of a great deal of torture, especially in heavy beams, if you drill the holes instead of punching them.

Mr. Horton—Drill them right from the solid?

Mr. Schaub—That is what is intended, and it is very satisfactory work. In regard to the value for riveting, mentioned by Mr. Horton, those are the old values that were based on the old shearing value of steel, on which the effect of the knives came into play. Now, when we only work material up to the elastic limit, we do not cut it with the knives, and that is the basis of those values, the shearing values, obtained by experiments in torsion, and they are very complete. If we use shearing values from actual experiments with knives, we find the effect of the knives varies all the way from 10 to 30 per cent, and we really do not get a true shear, because the effect of the knife may be one thing and it may be another. The bearing value was taken as double the shearing value, because that seems to be the accepted rule in all the standard specifications.

Mr. Modjeski—With regard to Mr. Condron's remarks on punching, I would say that I have probably not made myself clear as to

what I consider the diameter of the punched hole. I believe that when the punched hole is mentioned it should refer to the clear opening or the diameter of the punch. I have been in the custom, lately, of specifying that for a nominal ⅞ inch rivet the diameter of the die be 11-16 inch, which makes the punch ⅝ inch in diameter. I wish to say here that, due to hurried reading of Mr. Schaub's specifications in this respect, I misunderstood his requirement, and that we are only at variance by 1-16 inch on the size of the die, Mr. Schaub requiring it to be ¾ inch diameter for a nominal ⅞ inch rivet.

As regards the difficulty in punching material with a small punch, Mr. Condron's remarks are correct. To offset this difficulty I have been limiting my sectional material for all ordinary work to ¾ inch in thickness. I would not attempt to punch ⅞ inch material with a ⅝ inch punch. I have not found any difficulty in punching ¾ inch thickness of metal with a ⅝ inch punch.

Mr. Schaub—What will be the diameter of the die in that case?

Mr. Modjeski—One sixteenth greater.

Mr. Schaub—One sixteenth more. That would be very desirable if we could get that done, but the shops object to punching that small in that thick material. They say it would break all the punches.

Mr. Modjeski—I have had it done in Chicago in two shops.

Mr. Schaub—It would be a very desirable thing if it could be done, because I agree with you that it should be done by punching the hole small and reaming it out to be the larger size.

Mr. Modjeski—Mr. Horton had about 1,000 tons of Northern Pacific work done last year. He might tell how difficult it was to have that done.

Mr. Horton—As far as punching is concerned there is very little trouble. By the way, we have just had occasion to punch ⅞ inch material with a ½ inch punch. The foreman said we could not hold the material together with ½ inch bolts for the reamers. We did, however, with little or no trouble. The relation of the die to the punch has much to do with the ease with which the work is done. We have specifications coming to our hands with the demand that the die be no more than 1-16 of an inch larger than the rivet used. This is wholly impracticable. Now, with reference to the question of reaming any exact amount—manufacturers usually work with punches and dies to punch holes for ⅝, ¾ and ⅞ inch rivets. It is very desirable, at least it simplifies matters, if the reaming may be so specified that some of those standard sizes of punches and dies may do the punching.

I noticed, early in the evening, some experiments with paper

models with reference to beams and girders, presumably with reference to the question of stiffeners. I said nothing in the paper I read, with reference to the stiffening of girders. I am reminded by the experiment, and the various suggestions that have been made, of the discussion in an engineering society some years ago when the specifications of the Pennsylvania road were being presented for discussion, wherein the specification required that stiffeners should be sufficient at intervals about the depth of the girders to take the entire shear, acting as a free column, the length of the depth of the girder. In the discussion, attention was called to instances of girders on the Grand Trunk Railroad. There were a good many girders 40 to 60 feet long down east, something like forty years ago, and they had a standard design—English; the webs were invariably 3-16 of an inch thick. There was not a stiffener on the girders from end to end, and when some gentleman asked the author if he knew that these girders had been in constant use for thirty years and no distress shown, he freely admitted he did, but for all that he wanted stiffeners.

Mr. Modjeski—With regard to stiffeners, I have had occasion recently to revise some plans, where the original stringers were designed with ⅜ inch web under the Pennsylvania specifications, which require a number of stiffeners and fillers under them. The plans were changed so that the web was made ½ an inch thick instead of ⅜, which, under these specifications, made the ratio of the thickness of the web to the unsupported distance sufficient to dispense with stiffeners altogether. The weight of the stringer was reduced on the nineteen foot panel by 450 pounds per stringer, and we have now a solid web, without any holes vertically through the center.. The original stringers were figured under Pennsylvania specifications on the basis that the bending moment is to be resisted by the flanges only. This requirement precluded a corresponding reduction of flange section so that the modified stringer is much stronger and lighter than the original design. I mention this also as a suggestion that specifications could be written which would entirely dispense with stiffeners on stringers, making the web thick enough.

Mr. Horton—Stringers do not generally require stiffeners under the Cooper specifications.

Mr. Schaub—In the specifications the distance from center of trusses for deck spans has been altered to read, "They shall not be spaced less than one-half the depth of the trusses at the ends, apart, center to center, and for deck spans shall not be less than 14 feet center to center."

Mr. Finley—I hardly agree with Mr. Schaub or Mr. Modjeski,

that it is a good idea to leave out the bottom lateral bracing. I believe the use of this bracing, in a measure, prevents vibrations due to the unbalanced condition of the live load.

I agree with Mr. Horton as to the tendency to excessive riveting in plate girders. I have frequently noticed in shops six or eight inch angles for plate girders punched so full of holes that they looked like a sieve, and it seemed odd that a man should punch away so much metal to fasten it together. I remember a number of cases in my experience where I have had occasion to take down old combination bridges that had floor beams with 5-16 inch web, no stiffeners, hung by yokes, and with the rivets spaced eight inches apart from end to end; yet I never discovered a loose rivet.

Mr. Horton—Have you ever discovered a loose rivet in service that came loose due to gravity loads anywhere?

Mr. Finley—Oh, lots of them.

Mr. Horton—In actual service?

Mr. Finley—Yes, sir.

Mr. Horton—From a gravity load?

Mr. Finley—Yes, sir; from a gravity load.

Mr. Horton—Where a stringer is riveted on top of a floor beam, or that sort of thing, rivets will always go loose; but with the rivets that actually carry stress it is a very rare thing to find them loose.

Mr. Finley—It just depends on what you would consider a loose rivet.

Mr. Horton—Well, we will take the problem of a connecting angle between the web of the stringer and the web of a floor beam as an example, where the stress is normal.

Mr. Finley—Well, it would be difficult to say about that. I have found any number of loose rivets in drawbridges, for instance.

Mr. Horton—We can understand that. Did you satisfy yourself that the bearing and shearing was within such limits as we are talking about?

Mr. Finley—I never saw a rivet shear in actual practice. Mr. Horton mentioned the tendency of the present time as a sort of a departure from the accepted practice of American bridge building —the pin connected bridge. I think there is a decided tendency to use riveted connections. I saw at an eastern shop, a short while ago, a bridge for an eastern road, in which they were using 1¼ inch side plates in the bottom chord, and drilling the holes. It was a Pratt truss with subdivided panels and riveted connections.

Mr. Condron spoke of the punching of steel, and limiting the diameter of the punch. I have seen shops in Chicago where they punched ¾ of an inch metal with a 9-16 of an inch punch.

Mr. Horton—I did not tell the whole story. The die was ⅝ of an inch there, too.

Mr. Finley—Speaking of testing specimens from thin rolled material or thick rolled material, I witnessed, just a short while ago, tests of some large I bars, 2⅝ inches thick, in which, in a number of cases, we got ultimate higher strength in the full-sized bar than in the specimen tests. I had occasion, also, to check, or to have checked, the carbon in some of the steel, and sent it to four different chemists, all experts in their line, and they didn't agree within 50 per cent in their results.

Mr. Condron—Were they all handling steel—engaged in daily testing and analyzing of steel?

Mr. Finley—Yes, sir. In my article on the Kinzie street bridge, I mentioned the chemical test on the steel from that structure. It was high steel, running up to 90,000 pounds—the limit that some one this evening said they were very much afraid of. That old bridge was in use nearly twenty years, and I was rather anxious to get the chemical composition of the steel, and I submitted drillings to two experts in this city (it was their daily business to give such results) and they did not agree within 50 per cent as to the carbon.

Mr. Horton—The question of reaming seems to have been remarked upon. From certain experiments we have had with drilling of material, I am disposed to say that, whenever it shall be demanded, manufacturers will get themselves in shape to do it, so that drilling will be done as economically as punching and reaming. In other words, if reaming has come to stay, in my idea we had better go straight to business and get punching out of the shop. It means simply the spreading of the shop over a large area. A drilling machine will make less holes in a day's work than a punch. We will have to have more shop room, possibly a little more cost of equipment. The labor would certainly be no more, probably less.

Mr. Finley—Your labor on these machines was less than the punching?

Mr. Horton—Yes; a large element of cost in bridge manufacture is the moving and handling. The punching and reaming means a second operation and handling. We had quite a little tonnage in one instance that was drilled out of the solid. We were surprised to discover that our labor cost on that work was as cheap as anything we had ever done on the same line.

Mr. Finley—I have heard other manufacturers say the same thing.

Mr. Horton—It is a question simply of "doing it." That is all.

Mr. H. P. Boardman—In regard to rivets working loose, I would say that we had a case of that on the Chicago & Alton road recently on a draw span. In nearly all of the four beams some of the rivets worked loose. Also, on another span on the road, a fixed span, the rivets have worked loose.

FURTHER WRITTEN DISCUSSION.

Mr. G. N. Linday—The method proposed in the paper of allowing for impact is no doubt an improvement, especially for the man who has to figure the areas of truss members. This rule, as well as all other common sense rules that we find in the different specifications, are all good and safe and more or less convenient to apply.

As it is not possible to find the exact effect of impact, due to imperfection of design and manufacture, one rule is as good as another as far as the final result is concerned. But it would, nevertheless, be interesting to find out what a theoretical treatment of the subject would lead to.

I happened to come across, some time ago, an article in a German publication in which the writer does this in a manner which seems to me to throw some light on the subject. Of course, it is not possible to find out the effect of impact in a structure theoretically, except for the simplest kind of loading. In the article referred to, the writer investigates the dynamic effect of a single load suddenly applied at any panel point of a truss, assuming that the load remains at the panel point after its application.

The question is: What is the deflection under the load, taking into account the inertia of the moving bodies, compared with the deflection after the structure has come to rest?

With the permission of the chairman I will give an outline of the argument and, in illustration, do some scribbling on the blackboard.

Suppose we have a truss of any shape, supported in any manner. If we want to investigate the deformation of this truss, as it passes from one state of equilibrium into another state of equilibrium through the effect of loads put upon it, without considering the inertia of the loads or of the structure itself, we make use of the law of virtual work.

If P is any load,

S the stress in any member,

d_s the deflection under P,

and Δl the distortion of any member,

that law is expressed analytically:

$$\Sigma P d_s = \Sigma S \Delta l.$$

or, in other words, the virtual work of the loads is equal to the virtual work of the stresses.

We may also write,

$$\Sigma P d_s - \Sigma S \Delta l = 0,$$

or, the algebraical sum of the work done is equal to zero.

This relation, then, holds good if no account is taken of the inertia of the loads or of the structure. But, if we want to take into account this inertia, we have to make use of the law of mechanics, which says that the sum of the mechanical work done by a material body in motion during a certain time equals the increment of kinetic energy during this time. The general expression of the kinetic energy of a body, which, from a condition of rest has moved under the influence of a constant force until it has acquired the velocity v, is

$$\tfrac{1}{2} m v^2$$

where m represents the mass of the body.

For a constant load P, that is for a load suddenly applied, the dynamic deflection would then be described by the equation,

$$\Sigma Q d - \tfrac{1}{2} \Sigma S \Delta l = \Sigma \tfrac{1}{2} m v^2$$

where the left side represents the mechanical work done by the constant loads and of the stresses, and the right side the kinetic energy. Now here it is to be observed that $\Sigma Q d$ is the mechanical work of all the parts of the moving structure, including the single live load, so that it is in reality composed of,

1. The mechanical work of the live load proper.
2. The mechanical work of the weight of the truss members, and,
3. The mechanical work of the weight of the floor considered as concentrations at the panel points.

Similarly, the sum $\Sigma \tfrac{1}{2} m v^2$ is composed of,

1. The kinetic energy of the live load proper,
2. The kinetic energy of the truss members,
3. The kinetic energy of the weight of the floor.

Having put down all these different effects upon the dynamic deformation of the structure, we can go to work and solve this equation in regard to the dynamic deflection y of the panel point where the live load is applied. It leads to a simple relation in which this dynamic deflection is expressed in terms of the static deflection of the same point under the influence of the live load.

And we arrive at the result that the *maximum* dynamic deflection y is twice as large as the static deflection, or,

$$y = 2 d_s$$

That is to say, that, if a live load is suddenly applied at a panel point, this point will come down twice as far as its final position at rest. The resulting internal stresses are then also in the same

proportion. In other words, under the loading mentioned, the proper amount of impact to be added would be 100% of the live load treated as a static load.

This is what Cooper allows, as is stated in the paper. But as a moving load on a structure is never applied suddenly to its full amount on a panel point, but comes on gradually along the floor, it should never be necessary to allow as much as 100%.

The argument here followed out, if it is right, would then lead to the conclusion that any practical rule which allows for impact within a reasonable distance of the 100% limit would be good and safe.

I want to say for the benefit of any member who desires to read the article I have mentioned, that it can be found in the *Zeitschrift fur Bauwesen*, of 1899.

Mr. Joseph Mayer—The author devotes one-third of his specification to an argument on impact and vibration.

In regard to the amount of impact we are informed that it is somewhere between nothing and the amount of the moving load. In regard to impact and vibration, the author suggests that their sum varies with the ratio of moving load to the sum of dead and moving load, without, however, giving any proofs.

Let us investigate, in detail, what happens:

First. When a load above the center of a beam, touching the same, is suddenly released.

Second. When a single load moves along a beam at the rate of 60 miles an hour.

Third. When a train moves along the beam at the rate of 60 miles an hour.

First. He assumes a beam 50 feet long, and a load which will produce a static deflection of ½ inch, suspended above the center of the beam, touching it, and suddenly released. The resistance to its fall is at first its own inertia and that of the beam. It will fall with an acceleration

$$\Delta = \frac{P}{P+CY} g$$

where P is the size of the load, G is the weight of the girder, g is the acceleration of gravity, and C is a coefficient equal to about ⅔, due to the fact that the average downward motion of the beam is only about ⅔ that of the load P.

As the beam is deformed it begins to offer a resistance due to its rigidity; this resistance gradually increases; the acceleration, therefore, diminishes. When the resistance to motion due to rigidity is equal to the load P, the acceleration of motion is 0, and

the velocity is a maximum. The deflection at this moment is the static deflection, assumed at ½ inch. From this moment on, the further motion is a retarded motion; the retardation is due to the fact that the resistance due to the rigidity of the girder is larger than the load P. The retardation of this part of the motion is at any point equal to the acceleration at a point equally distant from the static deflection. If R is the resistance to motion due to rigidity of girder, then

$$\triangle = \frac{P-R}{P+CG}\, g \qquad (1)$$

at any point of the motion. If we divide the whole motion of ½ inch, from the beginning to the point when the static deflection of ½ inch is reached, into four equal parts of ⅛ inch, and assume that, during these partial motions, the acceleration is constant and equal to their average accelerations, we will approximate sufficiently to the actual facts for our purpose.

Assuming G=25,000 pounds, P=60,000 pounds, then we have ⅔ G=16,667 pounds, P+⅔ G=76,667 pounds.

$$\frac{P}{P+\frac{2}{3}G}\, g = \frac{60,000}{76,667}\, 32.2 = 25.2' = \text{acceleration at the beginning}$$

of motion. The resistance R in formula (1) is proportional to the deflection of beam. In the center of the first ⅛ inch of motion, when the deflection is 1-16 inch, or ⅛ of the static deflection of ½ inch, R will be equal to ⅛ P; the acceleration at this point will therefore be ⅞ that at the beginning of motion, or $\triangle_1 = 22.05'$; the velocity V_1 attained after the first ⅛ inch of motion is

$$V_1 = \sqrt{2 \delta_1 s}$$

$$V_1 = \sqrt{22.05 \times 2 \times \frac{1}{96}}\,' = 0.6778'$$

The time t_1 required for the first ⅛ inch of motion is

$$t_1 = \frac{V_1}{\triangle_1} = \frac{0.6778}{22.05} = 0.03074''$$

For the second ⅛ inch of motion we have the average acceleration

$$\triangle_2 = \frac{5}{8}\, 25.2 = 15.75'; \quad S = V_1 t_2 + \frac{\triangle_2}{2}\, t_2^2$$

or,

$$t_2 = \frac{V_1}{\Delta_2} + \sqrt{\frac{V_1^2}{\Delta_2^2} + \frac{2s}{\Delta_2}}$$

or,

$$t_2 = 0.01331''; \quad V_2 = 0.6778 + 15.750. + 01331 \quad V_2 = 0.8874'$$

For the third ⅛ inch of motion we obtain in the same manner

$$\Delta_3 = 0.45' \quad t_3 = 0.0111'' \quad V_3 = 0.9923'$$

For the fourth ⅛ inch of motion we obtain

$$V_4 = 3.15' \quad t_4 = 0.0103 \quad V_4 = 1.024'$$

Finally we obtain for the time required for the load to produce the static strain due to it:

$$T = t_1 + t_2 + t_3 + t_4 = 0.0654''$$

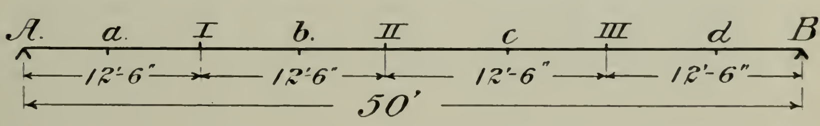
The largest velocity which occurs at the static deflection is 1.024′. The motion beyond the static deflection repeats the accelerations before it with opposite signs and in inverse order.

The maximum deflection is equal to twice the static deflection, and the time to attain the maximum deflection twice the time required for attaining the static deflection, or $T_1 = 0.1308''$.

The amount of impact under these conditions is, therefore, not dependent on the amount of dead load, but is always equal to the moving load strain, whatever the ratio of dead to moving load.

The dynamic deflection and the maximum flange strain in the girder will, however, be affirmed after a slightly longer time if the dead load is relatively larger, since the acceleration diminishes with the relative increase of dead load.

Second. A single load moving at the rate of 88 feet a second,



or 60 miles an hour. The load will take about ⅐ of a second to move over ¼ of the span.

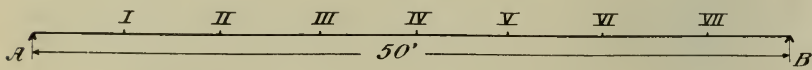
Instead of assuming the load moving over the length, a b, in ⅐ of a second, we shall assume it for ⅐ of a second at I, then for ⅐ of a second at II, then for ⅐ of a second at III. If we would increase the number of points and decrease the time for which the load stops at each point, we would gradually approach the actual facts.

This load here considered corresponds to one locomotive driver, and is smaller than the one before considered. The time required to produce the static strain will be about $\frac{1}{14}$ second, and the time to

produce the dynamic strain, $\frac{1}{7}$ of a second. The static strain at center, corresponding to position I of moving load, is $\frac{1}{2}$ the static strain when load is at II.

After the load has been for $\frac{1}{7}$ of a second at I, the full dynamic strain, equal to twice the static strain, will exist. At this moment the load is assumed to be transferred to II. The deflection is then equal to that which would be produced by the static load at II. For the next $\frac{1}{7}$ of a second there will be no change in deflection. There is no impact effect. After this, the moving load is transferred to III. The deflection is now twice that due the downward pressure of the load, and the girder moves up until there is no strain. The result is, therefore, that, under these conditions, the strain at center never exceeds the static strain. But this static strain exists at times when the load is at quarters.

Let us now divide the girder into 8 equal parts. Let the load



be successively at I, II, III, IV, V, VI, VII, at each point for $\frac{1}{14}$ of one second.

The static strain in center when load is at I is $\frac{1}{4}$ of the static strain when load is at center. After the load has been at I for $\frac{1}{17}$ of a second, the static strain due to this position of load will exist. Then the load is transferred to II. After $\frac{1}{7}$ of a second from beginning, the strain in center will be equal to the dynamic strain corresponding to position I, plus the static strain due to difference in position of load between I and II, or, in all, a strain three times as large as the one existing after $\frac{1}{14}$ of a second.

The center deflection at this time is $1\frac{1}{2}$ times the one corresponding to the static load at II. At this moment the load is transferred to III; the deflection corresponds now to the static load, and for $\frac{1}{14}$ of a second there is no change in deflection. Then the load is transferred to IV; and after $\frac{1}{14}$ of a second the deflection will have increased to correspond to the static load at IV, and the motion of the girder will be downwards. The load is now transferred to V. After $\frac{1}{14}$ of a second the deflection will be nearly $\frac{1}{4}$ more than the static deflection corresponding to the load at IV. After this, deflections decrease. The impact under these assumptions is, therefore, somewhat less than 25 per cent of the moving load.

From the above it is evident that the impact due to a single moving load, going at the rate of 60 miles an hour, over a 50 foot girder, is less than 25 per cent of the impact produced by a load suspended over the center of such a girder, touching it and suddenly released.

Third. A train moving at the rate of 60 miles an hour over the girder.

It will take about $\frac{4}{7}$ of a second for the train to move a distance equal to the length of a girder. It takes about $\frac{1}{7}$ of a second for a single load to produce the largest strain due to it, and this largest strain is less than 25 per cent in excess of the static strain due to it. The strains produced by any single load fluctuate around the static strain due to it, sometimes being smaller and sometimes larger. The fluctuations of the strains due to different loads are generally not coincident.

It is, therefore, evident that the total impact must be a rapidly decreasing proportion of the total moving load strain, as the number of single loads increases, since the fluctuations will soon entirely neutralize each other.

The increase of dead load has only the effect of diminishing somewhat the velocity, but not the amplitude, of the oscillations in live load strains, though the amplitude of the oscillations of members is diminished thereby. If the latter were not the case, the impact would be proportional to the sum of dead and live load strains.

The writer, therefore, believes that the author's assumption that impact varies as the ratio of $\frac{L}{L+D}$ is not correct, and that a clause in the specifications diminishing the impact with the length of moving load producing the maximum strain in member considered is more correct than the author's adopted clause.

There are in the specification, itself, various clauses of doubtful expediency. Section 1 prescribes that the width of deck plate girders shall be uniform for all spans. For plate girders near 90 feet in length a width of 8 feet would be more desirable than the prescribed width of 7 feet.

Section 2 prescribes a very unusual clearance, increasing the cost; this would better be left to the railroad companies to prescribe. The width of truss spans of $\frac{1}{15}$ would be uneconomical for spans above 500 feet.

Section 3 prescribes the omission of bottom laterals in deck spans. This would be inexpedient in long spans.

Section 6 prescribes the furnishing of tracings to the railroad company before construction is commenced; this would often entail the unnecessary expense of making two sets of tracings.

Section 11 prescribes a speed which is absurd for strong curvatures, and which would be entirely unsafe. The centrifugal forces prescribed for such cases are therefore excessive. The observations made do not justify the excessive amount of impact pre-

scribed for long floor beam hangers. The moving load given would be excessive for the majority of railroads.

Section 14 gives a column formula which does not agree as closely with the actual tests as do the ordinary straight line formulas, which are more convenient for use. The fibre stress given for timber is excessive; the various timbers are much less uniform than steel, and a larger factor of safety should therefore be used for timber than for steel.

In Section 15, the sections prescribed for alternate strains are excessive. If half the smaller section is added to the larger section required, there will be ample provision.

In Section 17, the top flange proposed for deck girders is objectionable, on account of its small radius of gyration; it is uneconomical with short spans and shallow girders.

Referring to section 28, the usual standard of 0.08 per cent for phosphorus gives a satisfactory steel. Before any change is made it would be desirable to have the evidence which shows that the increased cost is justified by the improvement in quality obtained.

Referring to section 29, it is usual and desirable to prescribe the maximum permissible sulphur for rivet steel at about 0.03 per cent to avoid hot shortness, otherwise the specification appears unobjectionable.

Mr. J. W. Schaub—In view of the discussion offered at the last meeting, I am inclined to believe that some of your members did not understand the object in view in presenting this paper. My object was not to write a new specification (there are a great many now to choose from), but rather to present a new method of proportioning steel bridges.

In the usual method of proportioning, we have been providing for the effects of the moving load in some vague manner by reducing the known values of materials to resist the forces which come upon them. In other words, we recognize that these values have all been obtained from tests made on a testing machine, which involves conditions totally dissimilar from those existing under the effects of a moving load in a bridge, so we have been reducing these values, in some cases by one-half and in others by one-fourth, to allow for the effects of the moving load.

The purpose of this paper was to present a study of the effects of a train moving at high speeds as compared to a fixed load, as shown by the valuable experiments made by Professor Turneaure, in 1897, and the impact formula

$$\frac{I}{L} = \frac{L}{L+D} - 0.55$$

certainly coincides with the observed effects better than any yet proposed.

Referring to Mr. Modjeski's suggestion—to the use of 18,000 pounds per square inch, instead of 15,000 pounds, as a basis of unit stresses—I would say that I agree with him, in a measure; but when we review all of the tests made on full-sized members, we find, as a rule, that the elastic limit is below the elastic limit obtained from the small tests made on the same material. This is a very natural result, for all of our designs are full of small eccentricities and extraneous material, all tending to vitiate the perfect distribution of a load on any member, so that I am still inclined to think that 15,000 pounds per square inch is the better basis for a fixed load, in proportioning any member.

In regard to the punching of ⅝ inch diameter holes in material ¾ inch or more in thickness, I am surprised to learn that no difficulty is found in doing this. The Michigan Central Railroad Company requires for ⅞ inch diameter rivets to be punched 11-16 inch diameter, and then reamed to 15-16 inch diameter, which is the same as called for in this paper, and the experience in the shop shows this to be about the limit for punching in material ¾ inch thick; so that they specify that all holes in steel more than ¾ inch thick shall be drilled. Moreover, I doubt if the advantage obtained in reaming 5-16 inch in diameter is not more than offset by the injury to which the material is subjected in punching holes which are smaller in diameter than the thickness of the material, to say nothing about the difficulty met with in the shop due to the breaking of the punches. However, I would like to hear some further discussion on this matter.

Replying to Mr. Mayer, I would say that no argument is presented in the paper anywhere, to show that the value for impact alone should be somewhere between zero and the amount of the moving load. The statement in the beginning of the paper, that a train may be taken as falling freely to the extent of the deflection of the structure, as a whole, is a condition which is never realized. On the contrary, I took pains to repeat Professor Turneaure's statement that the effect of speed alone, as applied to impact, is of no practical importance, unless it be for very short spans, say 40 feet long. Mr. Mayer is nearly correct in his deductions that, for a span 50 feet long, the impact alone would be about 25 per cent; and it can further be shown that for a span 100 feet long no impact need be added at all (Transactions American Society Civil Engineers, Vol. XLI, p. 426), all of which rather confirms the statement of Professor Turneaure.

However, Professor Turneaure has shown that the vibration

produced by a train moving at a high speed is of far more importance than the effect of impact alone, and as the inertia effect of the moving load is the direct cause of impact and vibration, it is assumed that the ratio of the moving load to the total load must be a measure of this effect. This is so evident that it needs no proof, but Mr. Stone in his paper on the "Determination of the Safe Working Stresses for Railway Bridges," (Transactions American Society Civil Engineers, Vol. XLI, p. 541), demonstrates this assumption.

Professor Turneaure has shown, by his experiments, that for short spans the value for impact and vibration should be 40 or 50 per cent of the moving load, and the values given by the formula

$$\frac{I}{L} = \frac{L}{L + D} - C, \text{ equation (1), when ``C'' is taken at 55 per cent,}$$

meet the results of Professor Turneaure's observations very satisfactorily. By varying the value of "C" in equation (1) the value for impact and vibration can be made to suit the views of almost anyone. In the specifications the value for "C" was taken at zero to provide for all possible contingencies.

I agree with Mr. Mayer, that a width of 8 feet for a 90 foot girder span is more desirable than 7 feet.

The 16 foot clearance is not unusual, and has been adopted by several prominent western roads, as previously stated.

Clause 2 has been changed to read, "Trusses shall generally be spaced about ½ the depth of the trusses at the ends, apart, but not less than 14 feet c. to c. of trusses for deck spans."

Clause 6 provides that one set of prints shall be made on linen, and does not call for the tracings as Mr. Mayer supposes. These prints, on linen, are for the erector and are more durable than if made on paper.

Clause 11 calls for a speed of 90 feet per second, or 60 miles per hour, on curves, which is not absurd by any means, as it is quite commonly used. (See specifications Michigan Central R. R., 1896.)

The moving load given is not excessive at the present day, and has been adopted by a number of railroads. In fact, this load is already exceeded by the Pittsburg, Bessemer & Lake Erie R. R. The fiber stress given for timber is for fixed loads, and when the proper value for impact is added the final result is practically the same as given by the usual methods of proportioning.

As to clause 15, I am inclined to agree with Mr. Mayer.

The top flange proposed for deck plate girders, clause 17, should apply only to spans about 60 feet long and over, and adds only about 2 per cent to the weight of the ordinary design. This form

of top flange is not new, and has been adopted by several western roads. Its advantages are more than offset by the increased cost.

The phosphorus limit of 0.06 per cent is not unusual and is met by the manufacturers without any increase in the price. It may be desirable to prescribe a limit to the sulphur in rivet steel, but my experience has never demanded it.

I beg to thank all of your members for the kindly discussion.

C.

TRANSITION CURVES.

By J. H. Lary, M. W. S. E.

While appreciating the fact that a great amount of information has been published upon the above subject, still I consider the question open for discussion until transition curves are more generally used.

The principal objection I find against transition curves, is the trouble of staking them out. The additional cost of construction involved is nothing on a new location, and is often nothing, or very small, on reconstruction, even if the improvement is only relining and ballasting track.

Many of the different systems of transition curves improve the track, and all of them that are on the principle of a cubic parabola, or what is commonly called spiral, are very effective.

I have used Searles' system of spirals, running the spiral in with the transit by varying deflections. I have also used an empirical formula, staking the spiral out by tangent offsets. This formula is

$$\tfrac{1}{2} L = 186 \sqrt{O / D}.$$

L = length of spiral in feet; D = degree of main curve; O = offset of curve in feet.

These two systems are very different in field work, but obtain practically the same results—a cubic parabola.

While the spiral seems simple enough to a person who understands it, yet it requires considerable tact to make both spirals and the regular curve properly fit the conditions; and when one is dependent, for the economy of the work, upon instrument men and engineers of limited experience, a complication in calculation or a cumbersome system is immediately apparent in the results. While an engineer should never allow instrumental or mathematical difficulties to stand in the way of obtaining the desired results, the lack of appreciating the ignorance a practical man has to contend with is evidently the reason theoretical spirals are not more generally used.

From my experience in spiraling track, I conclude:

First—The system should be simple and flexible, to allow for the careful adjustment of the simple curve and tangent by the usual methods of field operation.

Second—The spiral notes should be few and plain, to provide a clear record and to facilitate plotting the alignment.

Third—The form should be a cubic parabola and long enough to make an easy change from level cross section to full elevation. Then the trucks adjust themselves gradually and every point on the curve has the proper elevation.

Fourth—It should be so marked on the ground that any section man will know how to line and surface track without further instruction.

While endeavoring to deduce a very simple system for railroad spirals, I investigated the above empirical formula. Among the following paragraphs you will find several assumptions that are taken from Tratman's "Track," and which are similar to what I find:

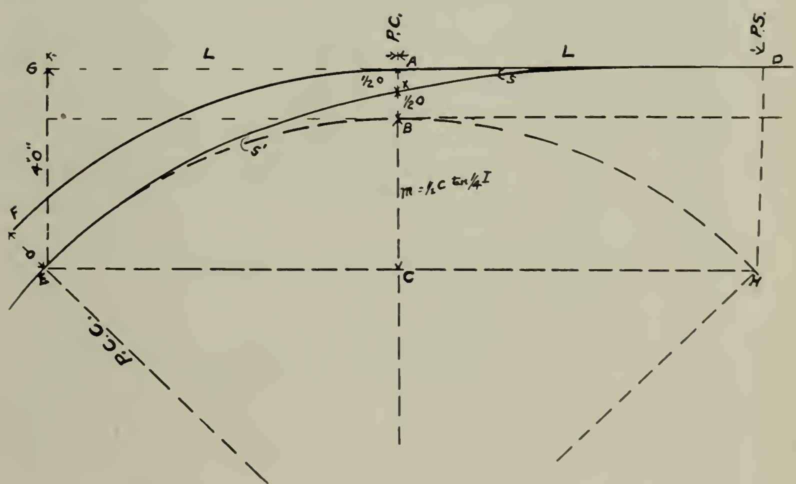
1. The transition curve will deflect exteriorly from the given main curve, because the rate of curvature becomes continuously less.

2. It will terminate in a tangent parallel to the given tangent, because the same central angle is consumed.

3. The offset A B bisects the transition curve D E.

4. The transition curve D E bisects the offset A B at X.

5. The shift S offset from the tangent varies as the cube of the distance from D, and is equal to the shift S^1 offset from the curve, which varies as the cube of the distance from E.



6. From the nature of the parabola the tangent offset increases as the cube of the distance; ∴ G E = 8 A X.

O = A B = 2 A X = ¼ G E = ⅓ M. M is the middle ordinate B C and = ½ C tangent ¼ angle.

Assume D = 1 degree, and L = 1 sta. or 100 feet.

Then M = .873 and O = .291.

From the nature of a simple curve M increases nearly in direct proportion as D, and as the square of the distance L.

$\therefore$ O = .291 D (L^2).

O = offset in feet. D = rate of curvature in degrees.

L = ½ the length of spiral in stations.

Now, the easiest field work is to run in the tangent D A and curve A F, etc., with P C at A, ignoring the spiral entirely, except to make mental allowance for the probable offset O. The distances are measured on A D and A F and the rate of curve given for A F. Then O is calculated, and the curve is offset to B E etc., and the stakes shifted to spiral.

Now, the error in assuming the rate of the original curve instead of the offset curve in using the distance A F instead of L, and in assuming the variations of M for a simple curve, would make faulty alignment if the spiral is staked out from the tangent produced A G, or from the offset curve produced B H, but the error is not serious when shifting both ways from the center.

Assuming a considerable error in the calculation of O, at X it is one-half as much, and by shifting the spiral from D to X and from E to X, it is overcome gradually and we have a transition curve that is in every respect superior to a simple curve; and the nearer we approach the true solution of O, the nearer we arrive at the cubic parabola which is the ideal form.

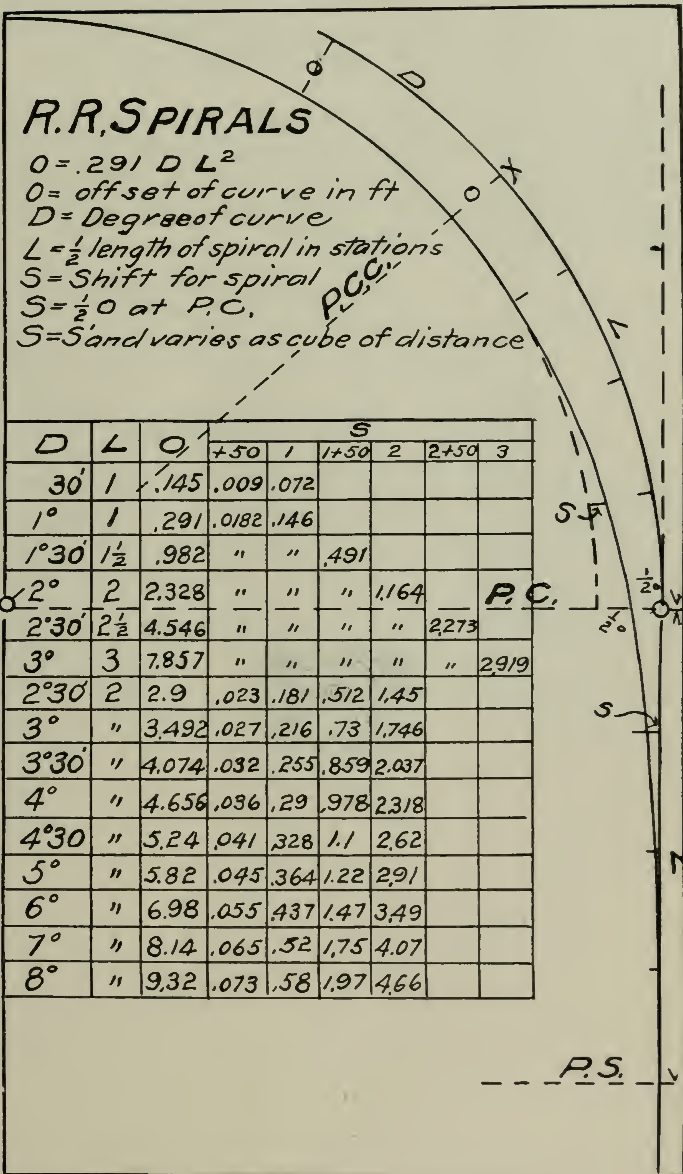
A constant can be used more closely fitting the conditions of the predominating sharp curves and lengths of spirals that will probably be used on a line or division.

A sketch of a sample spiral, the form O = .291 D L^2, and a table of distances for L, and O, and S for 50 feet intervals, for the common curves, can be made on one page to go in a common field book. This can be used directly for new location and is sufficient for preliminary data on old track.

The field notes will then appear and be platted as is the usual method for the original curve.

On new location the original curve can be run in regardless of spiral, except that it is advisable to set stakes at 50 foot intervals each way from the P C, for the length of the spiral, regardless of sta. and plus., and the same at P T. An axman can then go back and offset the stakes when the line is adopted, or in flat country such work can be left entirely for the construction party.

On relining old track use the same procedure except to use nails; when fitting the original curve, offset the stakes and pull up the nails. All of the preliminary work and calculations are done on the simple curve. For instance, run the intersection measure the external distance, subtract the probable O distance and calculate the degree of curve.



D	L	O	S +50	S 1	S 1+50	S 2	S 2+50	S 3
30'	1	.145	.009	.072				
1°	1	.291	.0182	.146				
1°30'	1½	.982	"	"	.491			
2°	2	2.328	"	"	"	1.164		
2°30'	2½	4.546	"	"	"	"	2.273	
3°	3	7.857	"	"	"	"	"	2.919
2°30'	2	2.9	.023	.181	.512	1.45		
3°	"	3.492	.027	.216	.73	1.746		
3°30'	"	4.074	.032	.255	.859	2.037		
4°	"	4.656	.036	.29	.978	2.318		
4°30	"	5.24	.041	.328	1.1	2.62		
5°	"	5.82	.045	.364	1.22	2.91		
6°	"	6.98	.055	.437	1.47	3.49		
7°	"	8.14	.065	.52	1.75	4.07		
8°	"	9.32	.073	.58	1.97	4.66		

With track centers set every 50 feet, and a guard stake 2 x 4 inches by 4 feet set on the side of the bank marked P S and the length of spiral, and one marked P C C with the rate of curve and amount of elevation, any section foreman, after he has seen one spiral lined and surfaced, will maintain them in good shape and take a pride in them.

I believe any spiral is better than none at all. And it is surely a bad situation in which a curve cannot be spiraled in some way at a reasonable expense. All of the necessary engineering work for a spiral, over and above fitting a regular curve, can be done before breakfast if no other time is available.

SKETCH PLANS

OF

IMPROVEMENTS

PROPOSED BY LINDON W. BATES

FOR THE

HUGLI RIVER CALCUTTA INDIA

TO ACCOMPANY

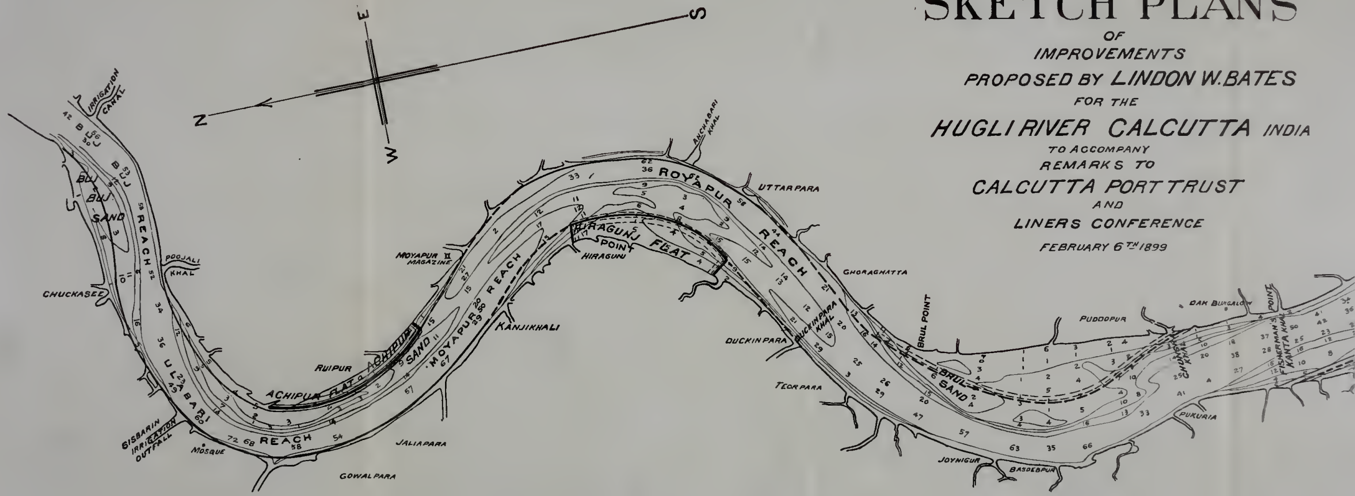
REMARKS TO

CALCUTTA PORT TRUST

AND

LINERS CONFERENCE

FEBRUARY 6TH 1899



BATES PROJECT

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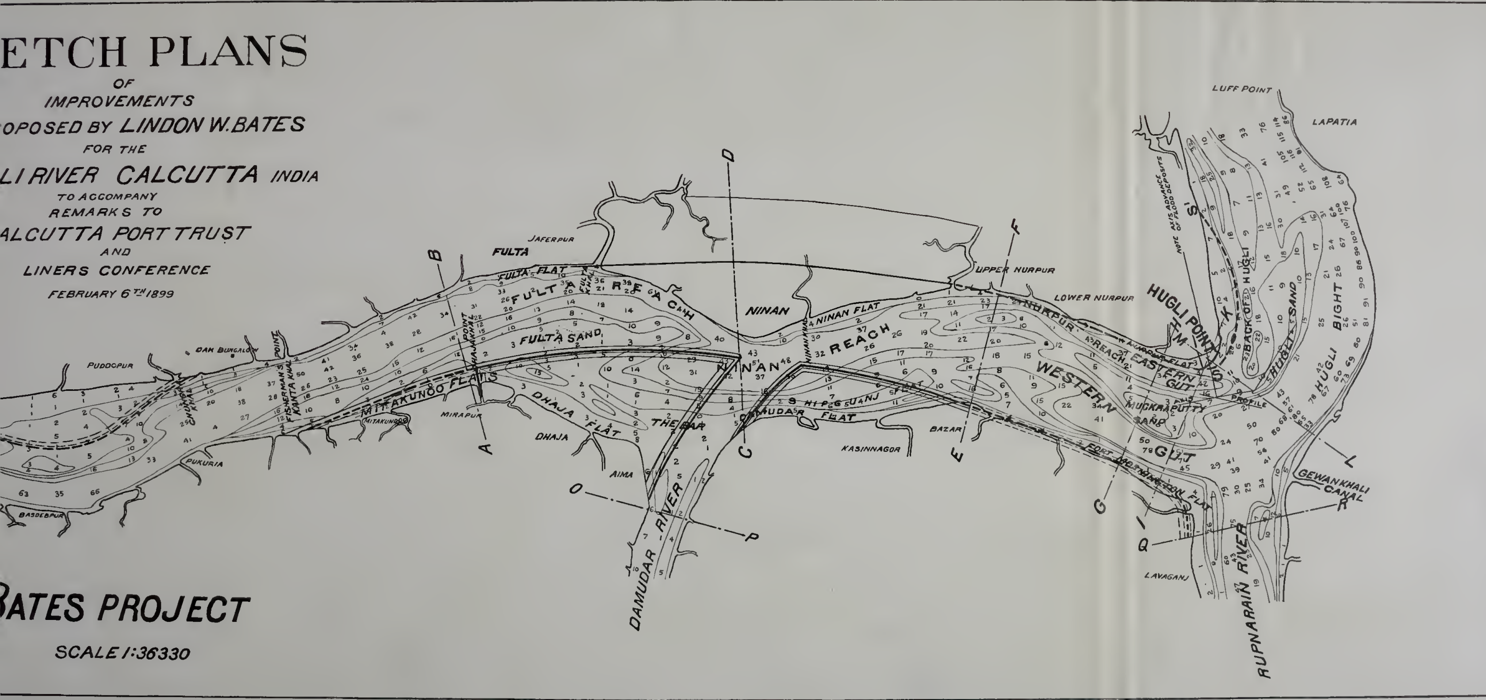
Western Society of Engineers.
Vol. V. No. 5.—Fig. 1.
Bates—Hugli River—Proposed Deep Water Approach to Calcutta.



HOOGLI RIVER — PROPOSED DEEP WATER APPROACH TO CALCUTTA.*

By Lindon W. Bates.

From the days of the earliest British settlement on the Hoogli, its navigation has been both difficult and perilous. In view of its greater and greater importance to the growing Indian Empire, and of the many perplexed problems which its regime presents, the river has been studied by engineers the world over, and several within the last half century have reported projects for its betterment.

Physical Characteristics.

Physically, the Hoogli is one of the delta mouths of the Ganges. It is a tidal estuary, subject to variable fresh water discharges from the Ganges, and from the watershed of its three principal tributaries—the Damudar, Rupnarain and Haldia. The discharges from the Ganges at its annual flood are sometimes enormous, and always silt-laden. All the tributaries are subject to tidal influence. The Damudar and Haldia are normal tidal rivers. The Rupnarain presents the phenomenon of a very large bottle-shaped basin just above its mouth. This river, with its peculiar basin, the Damudar river, and the double Fulta Point concave, are together responsible for the chief phenomena of the currents and bars in the Hoogli from Fisherman's Reach to Hoogli Point. (See Figure 1.)

Between Fisherman's Reach and Hoogli Point is the river's difficult navigation and its main problem. Elsewhere, except at the Moyapur and Royapur crossings above, a deep channel swings from concave to concave in admirable fashion.

The Rupnarain basin acts upon the incoming flood tide like a huge suction pump, and draws its axis irresistibly toward the Mornington bank opposite Hoogli Point. It has scoured here the only deep flood-tide channel (between the Muckraputty and Mornington Sands) to be found along the whole course of the river. From this, the western gut, the flood trends toward the Ninan concave, and with the help of the Damudar suction crosses again toward the west bank, making a variable and small channel among the Fulta Sands. After the expansion at the mouth of the Damudar, the flood rearranges itself in the straight Fisherman's Reach, and proceeds up the river without further travail.

*This paper was originally prepared for presentation before the Western Society of Engineers. It appeared, however, some weeks ago in the Proceedings of the Eighth International Congress on Navigation.

Scouring Action of the Tides.

It has been contended that the flood tide is the main scouring producing tide, but this statement is at variance with every modern authority. The ebb tide channel is, the world over, almost invariably in tidal rivers the navigated channel, because it is deeper, and the Hoogli is no exception. In it the eastern gut, an ebb tide channel, is the navigated course. The ebb does the most effective scouring work, because it has a place to take the alluvial to the sea, while the flood tide, Sisyphus-doomed, has no final place at which to free itself of its load, but must deliver its burden to some shoal, or to the no less industrious but more successful ebb. The ebb is the effective "worker" when it has the chance.

Tidal and Freshet Channels.

Navigation is, beyond question, best served when flood and ebb traverse a common channel. When from natural causes their axis is not the same—and it is impossible from physical or financial considerations to compel them to the ideal regime—if one must be favored it is best to give the working chance to the ebb. Little commercial reliance is anywhere placed in flood tide channels. Further, the freshet channel is necessarily coincident with the ebb channel, so that the vast preponderance of effective silt-moving effort is along the ebb tide axis. The flood tide has, with all its opportunities, scoured no deep navigable crossing from the western gut to the Ninan Reach (only three or four feet), while a variable part of the ebb, tormented by the combined action of the upper Fulta concave, and the variable tidal and fresh water discharge of the Damudar (at the Ninan bar) has yet partially reasserted itself, and succeeded in securing a deep pool from Ninan to Hoogli Point, and the several tracks navigated across the James-and-Mary bar.

Obstacles to Navigation.

The obstacles to navigation in the Upper Hoogli are:

1. The James-and-Mary bar.
2. The Ninan bar.
3. The doubling of Fulta Point.
4. The Royapur bar.
5. The Moyapur bar.

No plan of improvement has been adopted, and naturally, therefore, none has been executed to improve the conditions at any of these places, except the Leonard attempt at Moyapur.

There has been evolved, however, a most perfect intelligence department, giving daily, and often hourly, information, and this

in turn sustains a highly developed pilot service. These measures secure the best results possible under the present infinitely variable conditions of tracks and bars. But there are inevitable delays in going up and down, and very present dangers, which, even in favorable times, keep pilot, captain, crew and passengers alert, nerved, and prepared for an emergency, since to sheer, to touch, may be fatal. It is not alone the James-and-Mary, Ninan and Moyapur bars, but the doubling of Fulta Point also which now need bettering in the interests of safe navigation. In the reports of previous engineers, there is no serious recognition of the ruling parts which the Rupnarain basin (just inside the heads) and Fulta Point, with its double concave, play in the river's derangement. A double concave is always a bad thing, and sure to give trouble. When it is further complicated by the eccentricities of such a stream as the Damudar, the case is worse. No survey of the Rupnarain basin is available, but it contains many square miles.

Remedial Projects.

(A) Those which would utilize the Hoogli from the sea to Calcutta for the navigable approach, and which seek to increase and render stable its ruling depths.

(B) Those which would utilize the river in part, and which propose canals for the rest.

(C) Those which abandon the Hoogli and contemplate the use of another Ganges mouth and canal.

Under A are grouped the formulated projects of various engineers; the suggested diversion of the Damudar into the Rupnarain, or of both into the Haldia; and the Hoogli Point cut-off scheme.

Under B are placed the Diamond Harbour and Calcutta Canal, and the canal from Diamond Harbour near Hospital Point to Fisherman's Reach above Fulta Point.

Under C is placed the Mutla Canal proposition.

The various projects enumerated under the last two groups have been eliminated from probable realization. Technical and public discussion, self-evident difficulties, and a cost manifestly in great excess of a sum obtainable and warranted, have placed them beyond the pale of serious entertainment.

It should, however, be remarked that the canal from Diamond Harbour to the Kiddepore Docks has not been examined lately with reference to the economies of modern excavating tools. These could now assure a wider and deeper canal for an expenditure materially lower than the estimates of ten or twelve years ago.

But as the river is itself, so to speak, a canal already built and

needing only regulation in a few places to become in commercial efficiency superior to any other possible canal, the writer confines his attention to the Hoogli and its tributaries, and this analysis concerns in consequence group A alone.

The various projects advanced under group A may be arranged in five classes.

I. Those which propose raking, or scraping, or mechanical agitation, with the expectation that the tide will carry the material away.

II. Those which propose dredging alone through the river bars from Saugor Island to Moyapur.

III. Those proposing diversions of the tributaries, or of the Hoogli.

IV. Those advocating the construction of submerged dykes, jetties, or training walls, and reliance on natural scour after such regulation to erode deeper channels.

V. That recommending a system of training banks or walls and the removal of Fulta Point, in order to bring the river to normal width, and to an alignment adopted in consonance with calculations based on modern hydraulic principles for river regulation; in order, also, to regulate the propagation of the tides and fresh water discharge.

Class 1.

Mechanical Agitation.

In the first class, interesting and yet unsuccessful attempts have been made. All these measures fail, for the simple reason that bars exist between two eroding "fields" (to use an electrical simile) and the current is rarely able to carry material stirred up into the next "field," but merely drops its unwilling load close to the mechanical device. Mechanical agitation will succeed only when a device is perfected which acts effectively and covers the distance between the selected contours at the same time. Agitation must be so extensive as to give material no chance to precipitate, until carried past the bar.

Class 2.

Dredging in Hoogli Estuary.

It has been suggested by several, and the writer affirms it as certain, that for securing and maintaining better depths from Diamond Harbour to the sea, dredging must be and can be confidently relied upon, providing a proper plant is employed. This should excavate along an axis, selected after due surveys, and mod-

ified as changes occasioned by floods and deposits may make such desirable.

Dredging at Moyapur and Royapur.

The possibility of conducting successful dredging at the Moyapur and Royapur is conceded and assured. Dredged cuts here will have some value, and a measure of permanence, but their duration in times of ordinary tidal fluctuation can be determined only by trial. The freshets will change the ordinary tidal regime, and, carrying anew vast quantities of silt, will surely restore the bars, in whole or in part. By dredging each recurring season after the annual flood the amelioration may be made valuable, but it will be perfected only when the river bed is brought to its true width and alignment.

A trial can be made at the Moyapur by the small dredge just built on the writer's system for the Kiddepore Docks. It may be employed at any time (except at the period of high water, when the depth is excessive), in any of the following ways:

(a) It may work radially, taking each cut to a width as great as 200 feet, along or across the axis of the bar, throwing the spoil to one side; or

(b) Using a bow and stern and side lines, it may take numerous straightaway cuts five feet wide, the cutter size, throwing the material 400 feet away.

(c) It may discharge wing and wing, i. e., to either side, and allow the current to carry the sand into the adjacent pools.

In these operations from 300 to 1,000 cubic yards per hour can be excavated during periods of low tide.

But to make the dredging relatively permanent, it is indispensable that the river should be brought to a proper width and alignment by training walls, as later stated.

Dredging on Ninan and James-and-Mary Bars.

On the Ninan and James-and-Mary bars, in the navigable tracks, dredging is a very much more difficult proposition. Only two or three hours a day could or would be allowed by the authorities. During these times operations will be hazardous, and what can be done must be subject to daily or even hourly variation. This Kiddepore dredge, however, will be too small to warrant that a proper judgment could be formulated before trial or even after assiduous effort.

The reason of this is that the causes of trouble would not be modified by her procedure. These causes are adequate to undo the work of dredging as fast as it is done along the navigated line. Therefore, the opinion is here recorded that little or no good could

be accomplished by such employment of this small machine, or other mechanical devices, directly, on the Ninan or James-and-Mary bars. For improving the doubling of Fulta Point by its removal, machines of twenty times the power would be desirable.

It is the writer's conclusion that reliance upon dredging along the navigated tracks on the James-and-Mary and Ninan bars is inadvisable, but might fortuitously do good temporarily, and enough to warrant occasional employment; that at the Royapur very little, if any, dredging will be necessary, when the river is brought to proper width and curvature above and below; that at the Moyapur (since the training banks must go in gradually) a certain amount of direct dredging through the bar will possibly have measurably satisfactory results, and will diminish in quantity when and as the width and alignment are corrected.

On the other hand, dredges may be easily employed to assist in making training banks, anywhere on the convex side of the river, without the least interference with commerce.

Class 3.

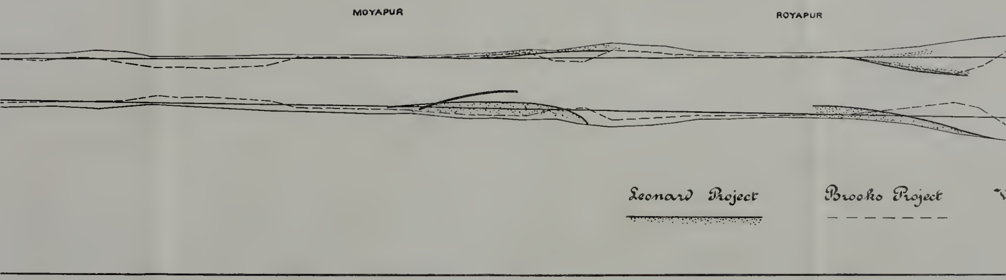
Diversion of Tributaries.

The suggested diversion of the Damudar into the Rupnarain is a very natural one, but several established facts militate against its advisability. Fulta Point is historically reported to have existed before the Damudar broke through its banks and made its present mouth. What the Hoogli regime was before this event occurred does not appear. The Damudar has now a tidal fluctuation and a fresh water discharge of variable volume. To a positive but variable extent it draws the flood tide to the west, already deflected in that direction by the lower Fulta concave. Its ebb forces the Hoogli ebb to the east bank, instead of allowing it to cross to the west from the lower end of the upper Fulta concave, as it would otherwise for the most part naturally do. The river Damudar, moreover, is commercially used and of importance to trade.

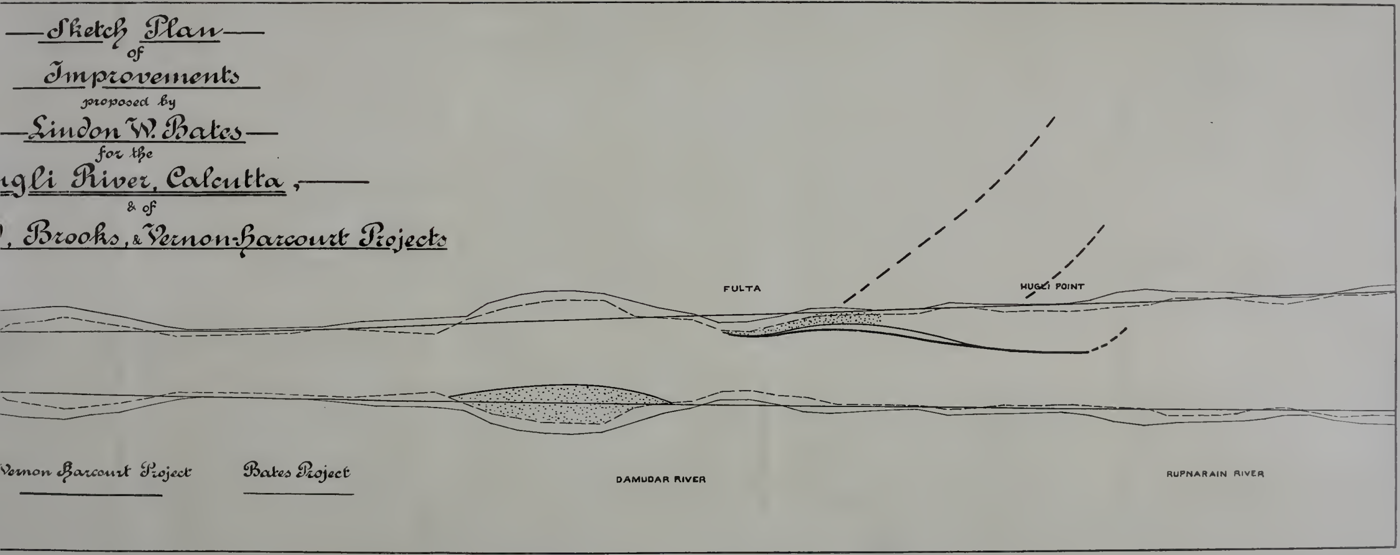
It could be diverted into the Rupnarain, and remain usable. But its tidal prism would be lost to the Hoogli above the Point, and the abstraction of so large a tidal volume is contrary to the accepted tenets of river hydraulics. Its tidal fluctuation and fresh water discharge would be added to that passing between the Rupnarain Heads, and would inevitably augment the evils due to that river, without commensurate increase of the good accomplished by the Rupnarain tidal prism in helping to scour navigable ways through the bars of the estuary. The results of such diversion would form an interesting problem, the exact solution of which the

Hu

Leonard



WESTERN SOCIETY OF ENGINEERS.
Vol. V. No. 5.—FIG. 2.
Bates—Hugli River—Proposed Deep Water Approach to Calcutta



river itself (or an exact model) alone could work out. But, in general, the double Fulta concave would still exist and would exercise a still more confusing effect than now. The ebb then, as well as the flood, would cross to the west bank, but too high up to help the tracks into the western gut. The present navigable tracks over the Ninan and James-and-Mary bars, by the eastern route, would deteriorate in depth and there would be no surety that new ones, carrying even similar depths, would open into the waters of the western gut; much less could there be assured better conditions of navigation.

The whole trough of the river—from the lower end of Fisherman's Reach to Diamond Harbour—is full of irregularities, which mark the struggles of the waters and the sands. These irregularities the mere diversion of the Damudar would not change, hence numerous collateral works would be required for regularization. On account of the inherent impossibilities of abolishing the eastern gut, these must remain inevitably of a problematic or academic character.

Nothing is to be gained by diverting the tributaries, except in a project to open to navigation the western and close the eastern gut.

A Damudar diversion canal and dam, and the collateral works in the Hoogli, would be very expensive and the latter would be, during execution, an insufferable obstruction to navigation.

These measures become much more prohibitive when we come to consider the diversion of the Rupnarain and Damudar into the Haldia. Questions, obviously very serious, arise, relating to the cost and location of diversion canals, tidal propagation, effects on present channels and navigation, acquirement of lands, the results to local drainage, irrigation, cultivation and trade, the character and position of the necessary dams and regularization works; and to the time, methods, and expense of execution. The preliminary examination discloses a probable cost in great excess of the sums available and compels the elimination from serious consideration of these suggested diversions of the tributaries, or any radical interference with them.

Diversion of Hoogli.

The Brooks project (which is illustrated on the comparative chart, Figure 2) may be classed as a diversion of the Hoogli. Its factors are a cut-off canal of small dimensions back of Hoogli Point, and a jetty out from the west bank, whose purpose would be to deflect the down current into this cut-off canal, and thus cause an enlargement to the dimensions of a new river bed. By reason of

its easier bend, this, it is claimed, would effect the needed improvement.

It assumes that the river would take the cut-off course and enlarge the cutting. But there can be no certainty of this, without the entire closing of both the western and eastern guts—an enterprise impracticable, from executive, commercial and financial considerations.

Its line of thought, therefore, needs no detailed discussion; besides which, the project does not deal at all with the conditions around Fulta Point and the mouth of the Damudar and Rupnarain, and the Ninan bar.

Class 4.

Those advocating the construction of submerged dykes, jetties, or training walls, and reliance on natural scour after such regulation to erode deeper channels.

The subject has now brought itself to the serious reports and projects (some of which occupied attention three decades ago), and to the consideration of other means, to render the western a deep, safe, navigable route.

The improvement of the Moyapur, Ninan and James-and-Mary bars is recognized as a necessity in all the projects.

The betterment of the Royapur may become soon desirable, as vessels of deeper draught will seek Calcutta when the other bars are ameliorated.

The writer's projects, in addition, comprise in the estuary the ultimate use of a powerful dredging plant, constructed for employment above Hoogli Point, the normalizing of the expansions and contractions of the bed of the Hoogli, the abolition of the difficulties at Fulta Point, and the consideration of measures to minimize the irregularities of tidal propagation.

I.

Projects to make the western gut the navigable channel.

Under I, again, are several sub-heads:

(a) Directive and concentrative work in mid-river on the Muckraputty Sands to improve the Ninan and James-and-Mary bar depths.

(b) Directive works: Long or short spurs or walls to low or half tide, connected to the shore on one or both sides of the river at Moyapur, Royapur and Fulta Point, and having a current directive position.

(c) Changing mouth of Damudar so as to allow an ebb cross-over at Fulta Point.

(d) Regulation of tidal propagation.

A.

Mid-River Works.

The plan of the isolated construction in mid-river on the Muckraputty Sands, proposed by Sir Charles Hartley, has not been available for inspection, and local traditions do not enable one to know whether it was designed to be transverse or longitudinal. This uncertainty, and the fact that the proposer did not have the opportunity to inspect the situation nor to give it intimate study, compels one to pass with regret his unusual and interesting suggestions of thirty-five years ago. If such a work were transverse, it could aim manifestly at the James-and-Mary bar only, and could have no effect upon the Ninan bar and Fulta Point concaves. If it were found to be longitudinal, and to extend from the Ninan to the lower end of the Muckraputty Sands, its alignment could theoretically be such that the work would, by its concentrative and directive action, cause the partial eroding of the Ninan bar or the western gut tracks. It certainly does not essay to block the eastern and navigable channels, as do those in class B, following.

But the possibility of beneficial effect at the lower end of this isolated work is not so clear. A simple longitudinal work hardly affords scope for a safe concentration across the James-and-Mary bar. An artificial island or loop, wide at the lower end, might conceivably in theory unite the functions of a transverse and longitudinal work, and produce a measure of beneficial effects at both ends. It would thus occupy the site of the Muckraputty quicksands, of unfathomed depth, in the center of the whirling waters of Hoogli Point. In such form it might increase the velocity of the ascending and descending tides already sufficiently violent.

To the wreck of the "City of Canterbury" has been credited a better bar than existed before this memorable disaster. The wreck, though all but engulfed in these treacherous sands, is in its position analogous to a transverse work.

The design, the location, the proper material and plan, and method of construction, the cost, the effects and efficacy of the works that lie within the realm of this suggestion (which has a special value from the distinguished successes of its author) are worthy of attentive study by whatever commission shall some day be charged with an exhaustive and authoritative review of all alternatives offered for the Hoogli's improvement.

B.

Submerged Training Works.

The more one has to do with water, the more he respects it; the closer one lives to its moods and methods, the more insistently he will avoid crossing them, and, if set the task of mastery, guide always, but rarely and cautiously try to compel, even in a small river. But the several projectors under this division (illustrated on the comparative chart annexed) all appear to conceive the realization of academical ideals by measures of drastic compulsion in opposition to currents of tremendous power. The Leonard measures were comparatively moderate, though on such parts as found practical expression the river has long ago visited the chastisement of obliteration.

His were:

1st. Directive works consisting of spurs, or projecting training walls, on both sides of the river at the Moyapur and Royapur, as indicated on the comparative plan.

2d. The reduction of the expansion at the mouth of the Damudar in the manner shown on the plate (disclosing on the part of Leonard an apprehension of the situation here, which is not reflected in the analogous project).

3d. A training wall from Fulta Point down stream, half way to Hoogli Point, with a view to diverting the ebb into the western gut.

4th. The contraction of the mouth of the Rupnarain—a measure absent, also, from the kindred project under this heading, and aimed at improving the propagation of the tides referred to hereafter.

The spurs run out from the banks at the Moyapur crossing were tried and found wanting. They failed to accomplish the result sought—the erosion of the bar—and have vanished.

They were an impressive and sufficient lesson to the guardians of this waterway, of the truth of the principle that in this river, out from its concave banks—projecting beyond the low tide line into the fields of live and powerful erosive currents, which have secured its concave troughs—no works should be placed.

This is not to say that the banks shall not be protected from erosion by rip-rapping, or rectified by longitudinal training walls, near or above the average low tide line. Such precautions are feasible and desirable, and in common use elsewhere. It is one thing (and ordinarily a safe and wise thing) to have erosion-preventing works along a natural concave bank, but it is wholly another matter to put a concave training wall, of whatever construction,

into and across the concave trough of a river subject to twenty-one foot tides, bores and freshets—having a demonstrated ability to scour to a depth of 75 to 100 feet, and having currents with a recorded velocity of six, seven, and even eight knots per hour. Yet this is just what was first proposed in 1864, and revived in the project of December, 1896. It constitutes a necessary feature of these western gut projects.

Primary Tests.

Engineering remedies must not violate the fundamental, the elementary, principle of the art of improving commercial waterways, i. e., they must, first of all, be possible—possible technically, executively and financially.

But these measures (Figure 2) attempt deflections and ulterior contractions without reference to freshet and tidal regime, and inevitable effects. Tried by practical principles, the position of the recommended works is obviously without reference to the possibilities of execution and maintenance. At the Moyapur, the latter one essays to invade a concave eroded trough for over a mile. Below Fulta Point they would both cross and close the Ninan concave and the navigated tracks, and the latter one traverses for four miles the Muckraputty whirlpool sands. Such a work to be finished must be begun—begun at the ends, middle or bottom. If it is begun at Fulta Point or at Hoogli Point, the navigated course is first to be rendered hazardous by plant, craft and false work, and then to be blocked. If the middle section along the Muckraputty Sands is first put in, the procedure merely postpones the projected closing of the navigated route to a period when the difficulties of so doing will be enhanced by the rush of water through the gap. The tides unaided are not to be relied on to erode the millions of cubic yards necessary to open up a deep channel from Fulta Point into the western gut simultaneously with the closing of the eastern pass to shipping. Such wholesale work must be put upon the freshet, and a freshet time would hardly be a gap closing season. During the period of attempted construction, no idea even of an alternative route is presented for the vast and already enough hampered commerce of Bengal. It is not shown, nor can it be, how traffic can negotiate the eastern channels, barred by mattresses, piles and brickwork, blocks and barges. The mattress or wall placing methods employed at the mouths of the Columbia, Mississippi and Danube, at Tampico, Galveston, or anywhere else, afford no clue for a demonstration on the Hoogli that two bodies can occupy the same space at the same time. The western approach is to navigation a blind sand-barred passage, and in the best view would remain so for sev-

eral years. A construction blockade of unknowable duration could not but occur. An indefinite but long cessation of Calcutta commerce would ensue. Attacked by deep scouring currents, founded upon an unstable bed of concave alignment, and in a position which provokes erosion, the narrow wall, as planned, could not stand to be built, much less afterward endure topping by tides, bores and freshets, and the pressure and destructive action of attacking velocities.

Finally, financially, it could not be, as planned in December, 1896, built and made to stay, for the original estimate, or even for several times that amount. This remedy is therefore impossible from all the standpoints—technical, executive, commercial and financial—as well as from that of durability.

C.

Possibility of Utilizing Western Gut by Changing Mouth of the Damudar.

The above alternative is one considered by the writer when first examining and analyzing the subject. The elements of a project under this head would be:

1st. Removal of the Damudar outlet to head of western gut by means of training walls.

2nd. Excavation of the west bank of the Hoogli to form a new west bank for the Damudar below its present mouth.

3rd. Rounding off of Fulta Point.

Under such a scheme, the last two items are essentially feasible. But the first, the training wall, forming the east bank of the Damudar and the west side of the Hoogli, would present concave flanks to the ebb of both streams. For, if the Damudar mouth is moved, the ebb tide axis will cross to the west side, just below Fulta Point, cross on the west bank, and re-cross to the east side, spilling partly into the western gut. On the contrary, if we follow the flood, its axis will cross from the head of the western gut at the new outlet of the Damudar to the Ninan concave, thence from Fulta Point to the west bank, and then up Fisherman's Reach.

Because of the peculiar topography, the ebb and flood would have no common channel from Hoogli Point to the Reach, any more than now. The regime would not be bettered, the eastern gut tracks across the Ninan and James-and-Mary would deteriorate, and the tracks of the western route would not improve enough to be as deep as those on the other side. In the assumption that the walls could be built, and stay, harm and not good to navigable depths would probably result, even if a considerable amount of the ebb spilled into the western gut. Hence this alternative is too problematic to be recommended.

There are no other saving means to get the ebb, or any larger part of it, to cross to the west side. The idea of obtaining a common main ebb and flood channel through the western gut must, however reluctantly, be decisively abandoned.

D.

Improvement of Tidal Propagation.

Is it feasible so to regulate the tidal regime of the Damudar and Rupnarain, that the action of the Hoogli will be sufficiently bettered?

The less the volume of tidal fluctuation of these rivers, the more unhampered will the tide propagate in the Hoogli.

Either might be temporarily throttled — the Damudar even closed; but the tidal rise is so great that an increased difference in levels would cause such velocities at the Rupnarain gorge that the waters would restore the section in a short time by scouring vertically. This, in turn, would destroy inevitably the contraction works.

Leonard sought some promise in this direction, and shows spurs at the outlet of the Rupnarain. But no one since has had the temerity to advocate such a struggle with this stream. Successful contraction works are hardly possible in so short a throat.

There are no surveys to disclose the areas and depths of the Rupnarain basin. But it is shallow—only a few feet deep at low tide.

If through the lake a new bank were built with piles, fascines and dredgings, so as to establish a normal tidal river width, two alternative methods would become possible of governing the indraft and discharge of the Rupnarain:

1st. The abnormal tidal volume required to fill and empty the basin might be eliminated by a continuous septum. But this would radically diminish the volume available for scour in the estuary.

2d. The opening into the new basin—lying, say, south of the new bank—could be made at the upper end, some miles from the mouth, and a different tidal regime might be thus set up in the Rupnarain, and also for the Hoogli.

The technical and financial possibilities that lie within the province of this idea could only be fully developed after a careful survey, with tidal observations and computations, supplemented, perhaps, by an accurate working model.

The writer believes it would be concluded that the abstraction of a large part of the tidal prism would entail collateral work of

unknown expense and extent below Diamond Harbour, even if the Rupnarain were normalized. But possibly either palliative is one that might aid the regularization of the Upper Hoogli. They offer ways for bettering the tidal propagation of the Hoogli, and for adding, perhaps, to the depth over the James-and-Mary bar, and rendering most stable that anticipated by the main project advanced and supported by the writer. Either treatment would modify the action of the tides, the first much more than the second. The power of the flood to advance the Hoogli back sands would diminish, and the velocities up the western gut also. There are no other than these two ways to put a safe and durable brake upon the tidal velocities. The data, however, do not exist upon which to base a final judgment as to the amount of good which would ultimately result in either case, nor what would be the cost of the improvement.

The dredges employed to remove Fulta Point could readily construct a tide regulating bank through the Rupnarain basin, if the physical conditions should be found as favorable as it seems natural to expect.

It is not believed that the diminution of the flood velocity into the Rupnarain will sufficiently improve the James-and-Mary bar. It will rather permit the abnormal depth of the western gut to silt up, and render the James-and-Mary track more stable, though still inadequate.

The remedy does not touch the Ninan bar, or the conditions at Fulta Point. Hence, it is but a supplement to the regulation of the widths and alignment of the Hoogli.

Four opinions may be entertained, after due consideration of the data collected. One, that such regularization should precede the Hoogli project; the second, that it should follow it; the third, that it should be done simultaneously; and the fourth, that it should be executed only after the main regulation is accomplished, and it is found necessary to provide for ships of still deeper draft than the largest now passing the Suez Canal. To the last the writer inclines, reserving, however, a conclusive opinion until after a survey of the Rupnarain basin has been concluded and model experiments have been effected.

Class 5.

EASTERN ROUTE.

Evolution of the Author's Project.

The foregoing eliminations have brought the matter to the consideration of the only remaining alternative—the eastern route.

Fundamental River Bed Factors.

The bed of a river is defined chiefly by six factors, and is the resultant of all the forces acting through it. It has:

1st. Length.

2d. Breadth—the low water, high water, and average.

3d. Depth—the least, extreme, and average.

4th. Alignment—consisting normally of a succession of curves, the concaves first on one side then on the other, with occasional straight reaches between.

5th. Grade.

6th. Tributary beds,—and their like factors.

The principal object sought by the Hoogli improvement is increase of the least depths to a navigable standard. The change of any one of the other factors of the bed will modify depth.

The length of the river from Calcutta to the sea does not admit of material increase or decrease, consequently the depth, slope and velocity cannot be favorably altered through this factor.

It has been seen that the navigable depth cannot be permanently altered by mechanical means alone, or safely increased by the spurs or training walls so far considered.

The grade, or general level of the district, cannot be altered.

The tributaries may not be diverted, nor their tidal or fresh water volumes affected, without involving great direct expense, and indirect consequences of a serious nature to the estuary channels and other interests.

There remain, then, two factors capable of modification—width and alignment. Hope lies no other way. It is clear that if these factors of an alluvial bed are modified, the depth will be affected. If they are abnormal, the depth will be irregular.

Through these factors the cross sectional areas can be most naturally, cheaply and permanently normalized.

Normal Alignment and Widths.

A simple inspection of the accompanying maps will at once disclose the abnormalities of alignment. The principal ones are:

1st. The double concave at Fulta Point.

2nd. The sharp bend at Hoogli Point.

The first can be reduced by the excision of Fulta Point. The second cannot be done away with, though safe measures are feasible to give better direction to the ebb and flood, and to so serve an important and useful purpose. There are minor irregularities at different stages, often occasioning effects disproportioned to their apparent size. These are easily remedied. The range of tide and

freshet is so great that a correct high as well as low water alignment is desirable.

The abnormalities of the Hoogli bed are readily disclosed graphically. Curves derived from such a presentation are shown on Figure 1, accompanying. The low and high tide widths are platted. From a selection of normal widths the natural apparent lines of gradual expansion are deduced and drawn from Buj-Buj to the Damudar, and thence to Diamond Harbour, with allowance for the tributaries.

The high and low tide sectional curves show the Hoogli to be a succession of contractions and expansions.

The diagram automatically diagnoses the trouble at the Moyapur and Royapur crossings. It discloses that the low tide widths are here excessive, and points the remedy. It reveals the contraction at Fulta Point. It lays bare the expansions at Buj-Buj, Achipur, Hiragunj and Brul Sands, Damudur mouth, and at and below Hoogli Point. Where the river has a normal width it presents the best condition for safe navigation.

Results of Abnormal Conditions.

It is unquestionably wisest to have a generally uniform velocity of flow in a river. This is the condition of the least bar-forming disposition. An expansion causes a bar to form because the velocity is reduced, and a portion of the water-borne silt is deposited. A marked contraction or deflection causes the erosion of undue depths. An undue low tide width at crossings results in bars.

Ratios of Expansion.

Given a uniform velocity and a stable depth in a straight reach of a tidal river, the width must gradually expand by a ratio per unit of length. At a given station a certain width passes the tidal volumes of the river above, and at a station below the width must be proportioned to pass the first volume plus that of the tidal prism between the stations. Again, according to the ratios of expansion employed, one can vary the depth or the velocity. When a tributary comes in, its tidal volumes must be cared for in the regulated bed. The factors of the tributary beds are vital to considerations of tidal propagation.

From a small scale survey of the river one can graphically approximate the natural ratio, by selecting a number of normal sections, and striking average lines on either side. Close computations and observations are necessary to establish the best ratio, with reference to curvature and the depth sought, and to make a final location of the lines of rectification. Consequently, it is prudent to

make the reservations the writer made in putting out the preliminary project. But it is assuredly true that no material departure in principle from the lines shown is practicable on the Hoogli.

The alignment of the projects recommended is simply translated from the diagram to the actual river, having regard for its present curvature and an abiding respect for its erosive fields.

Guiding Factors.

The writer's conceptions of the subject have led him to a preference for a treatment which makes no possible struggle with these mighty waters and engulfing sands, which enlists the co-operation of the currents, and which, from beginning to end of the work, does not employ a craft of any kind in the navigated tracks to interfere with shipping.

Nothing should go into the deep water of this river on its concave side. Erosion of concave banks should be prevented or arrested, and the proper width should be secured at expansions by training banks placed where natural forces work for maintenance and not destruction. This is on the convex side. The excision of Fulta Point reduces two concaves to one and also abolishes a constriction. The long single concave will also inevitably carry both the ebb and freshet volumes past Hoogli Point and across the James-and-Mary bar, after abolishing the difficult navigation at Fulta Point and the Ninan bar.

To perfect the river bed at the Moyapur and Royapur crossings, it is necessary to bring the high water width to at least the present low tide width. This is a measure which must be led up to gradually. The treatment must begin by normalizing the expansions at Achiput, Hiragunj and Brul Sands, not necessarily by reclamations, as has erroneously been surmised was the purpose, but by new banks or walls.

Difference Between Reclamation, Training Banks and Training Walls.

A distinction has here to be drawn between reclamations, new banks and training walls.

Reclamations of the great expansions of the Hoogli involve vast quantities, would inadvisedly reduce the tidal prism, and are unnecessarily expensive measures. Training walls to low or half tide, swept over by freshets and tides, to be stable must employ great quantities of piles, fascines, rock or burnt brick. Rock is scarce and expensive. Low, quarter or half tide walls are usually dictated by motives of economy. They are admissible in rivers whose currents are moderate, whose tidal fluctuations are not excessive

and whose freshets are of but short duration. The Hoogli is not such a paragon. It is not a Weser or a Scheldt.

It is not possible to concur in the idea that a low training wall is everywhere better than a high training bank for the regularization of a river, when by skill under local conditions one is able to construct the latter for the same or less expense per lineal foot, and without diminution of the tidal prism, and besides normalize the cross sections by well directed dredging.

One is not able to subscribe unreservedly to the advocacy of low training walls where suitable material does not exist to insure stability, where tidal currents are notoriously violent, and where, for months, a high water freshet regime dominates the situation. Silt-laden freshets might use low training walls on the Hoogli to make such a series of new bars immediately below, that a year's work of the usual tidal currents would not suffice to erode them before another silt-laden freshet came.

In the Hoogli, with nearly the same water level on either side, a training bank on the convex side (rapidly, easily and cheaply constructed by a hydraulic dredge) with a wide base in combination with a structure of piles and fascines, and carried to a safe height above high water, affords the ideal local measure for regulating the width and alignment. A suitably placed opening will admit and discharge the tide if wished. It is to be stated, however, that an increase of the tidal volume will be provocative of increased velocities, while any radical diminution of the tidal prism is to be deprecated. The Fulta Point excision would add, if the enclosed areas on the convex side are tidal, nearly 600,000,000 cubic feet to the Hoogli's tidal volume. These areas may be made to act as reservoirs to scour the eastern channel, if deemed desirable, by the adoption of low training walls, if after practical trial such a structure will be found appropriate for Hoogli conditions. By the use of hydraulic dredges, moreover, low walls may be converted into high training banks, if it is demonstrated that low ones are unsuitable technically, or comparatively too expensive to build and maintain. In view of the Fulta Point tidal volume created, the writer regards the silting up of the areas behind the training walls or banks as not vital to the navigable depths sought. If, with the excision of Fulta Point (and the regulation of the Rupnarain, which surveys and model experiments may demonstrate to be desirable) it be found that low walls or shorter walls are cheaper and will serve all the needs of navigation, they should be adopted in the interests of economy.

Rectification.

From Calcutta to the Damudar no tributaries enter. The ratio

of width expansion of the rectified banks will be affected chiefly by centrifugal force, which varies with the radii of the curves. If, for preliminary purposes, this varying force is omitted from the calculation, the ratio would be practically unchanged from, say, Buj-Buj Sands (top of map) to the mouth of the Damudar.

Below this place the ratio must reflect the accession of the contributory waters of the Damudar and Rupnarain. The approximate natural average lines of expansion laid down on the diagram, showing the shape of the normal river bed, reveal the abnormal departures.

The amount of abnormal departure which can be tolerated varies with the navigable depth sought. The greater the depth desired, the less abnormal the width or sectional areas can be permitted to remain. The measures of correction to secure 16 feet of water are not the same, but less than those which would be required for 20 feet. This is particularly true at the Moyapur and Royapur, where the diagram discloses that there are large expansions above and below, and that the low tide widths at the crossings are too great. The low tide lines opposite these bars should be the high tide line. Were this so, the 18 feet contours of the concave troughs would merge and the bars disappear, so far as navigation to that depth is concerned, providing that the expansion either side were reduced to normal widths.

The Feasible Solution.

As it has been demonstrated that the western route is practically impossible, it is necessary to examine the eastern or present channel, and apply to it the same searching tests of possibilities. Having ascertained the normal river widths they are transferred to the actual river. The alignment should respectfully abstain from any serious invasion of the erosive fields of the concaves, and throw the regulation for the reduction of expansions on to the convex side, where such works will stand, if not topped by freshets and tide.

The left bank line is projected to cut away Fulta Point, reducing its double concave to one. It is carried thence round Hoogli Point, having regard to the guiding principle of normalizing the width so far as possible, without invading the erosive field. Such a course is tranquilizing, not combative. When this line is carried around Hoogli Point it does not contract the mouth of the Hoogli, but merely reduces the abnormal expansion below. It also fortuitously carries the ebb tide point of spill far enough to move the James-and-Mary bar into the powerful erosive field of the main river. It also directs the flood upon the same duty, with no needed change of the angle at which the Hoogli waters join those of the

Rupnarain. Pilots and ships would not here modify their present procedure, going up or down.

When an expansion is normalized by a training bank on the convex side, the ebb and freshet do not impinge with undue power on the concave bank. The radii of the curves are unchanged. A greater volume passing over the normalized bed will erode a bottom stratum, whose end area, with that of the section dredged to make the bank, will compensate for the end area of the excluded section. The flood tide will necessarily cease, tending to make channels back of the sands at Fulta, Brul, Harigunj and Achipur, and will follow the axis of the ebb; nor is it to be feared that it will attack concave banks which have resisted the combined attacks of the fresh water discharge and the ebb, and of annual freshets.

When the expansions, either side, are normalized, flood, ebb and freshet currents must approach crossings, such as the Moyapur and Royapur, along nearly common tracks, and, therefore, the least depths at the crossings will be increased, because all currents act in harmony, and the water is not permitted to dissipate its scouring power.

When the Fulta Point contraction is remedied (a single concave being substituted for the present double one), when the expansions opposite on either side of the mouth of the Damudar are normalized, a condition will be created which must produce far-reaching effects:

1st. It is perfectly clear to the navigator that when the point no longer exists, the present hazards of doubling it, going up or down, must vanish.

2d. It is conceded by even the most adverse criticism that the Ninan bar will inevitably be abolished. It cannot be otherwise, because within the long single concave the undiverted ebb and freshet currents of the Hoogli and the Damudar will have been brought to compass its obliteration at the same moment that the causes of its formation have been forever swept away.

3d. The volume of this bar-removing flow is composed of the following elements:

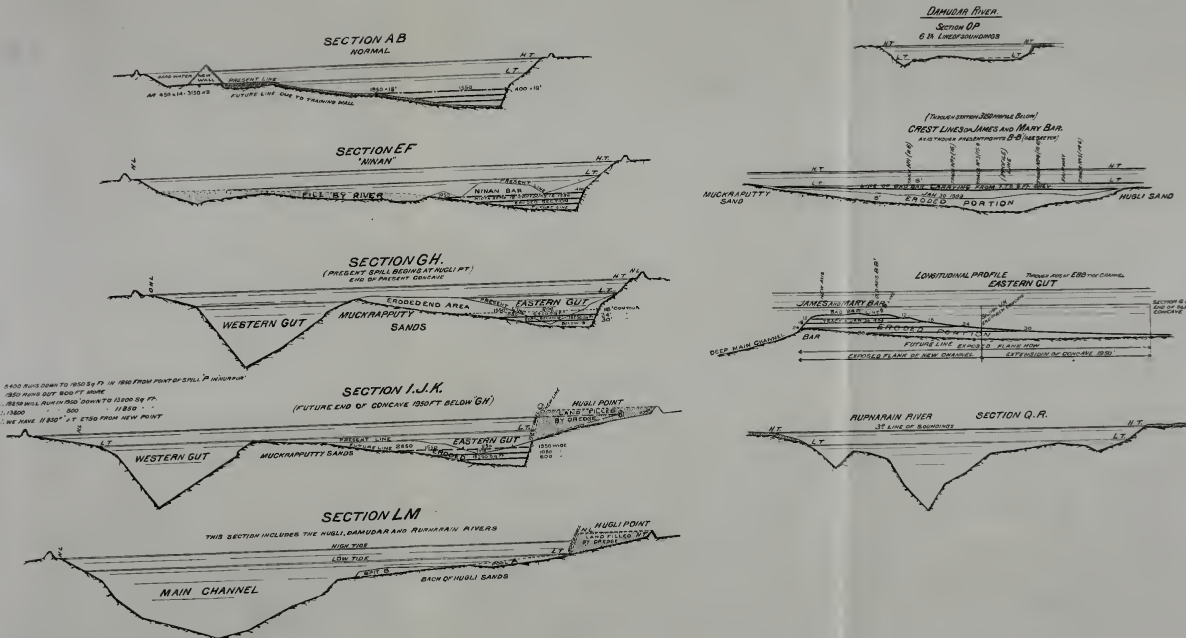
(a) The tidal prism of the Hoogli above the normal section A-B (see chart and cross section plan).

(b) The tidal prism of the Hoogli between A-B and the Ninan bar section E-F.

(c) The tidal prism of the Damudar river.

(d) The tidal prism of the convex basins which may be utilized to increase, if desired, the present tidal volume by 600,000,000 cubic feet, or to the extent of 1,000,000 cubic feet per minute,

Western Society of Engineers.
Vol. V. No. 5.—Fig. 3
Bates—Hugli River—Proposed Deep Water Approach to Calcutta.



equal to a stream 520 feet wide, 18 feet deep, and flowing two miles per hour each flood and ebb. These basins will very gradually silt up.

(e) The fresh water discharge of the Hoogli river.

(f) The fresh water discharge of the Damudar river.

To show graphically the effect which will be produced upon the Ninan bar, the normal section A-B, which contains only the elements "a" and "f" of the foregoing analysis, may be superimposed on the Ninan section E-F (Figure 3). This discloses that, without counting the other elements, "b," "c," "d" and "e," the width of the new channel under the single concave must not be less than 1,550 feet between the 18 foot contours, 1,080 feet between the 20 foot curves, and 800 feet at the 30 foot plane, and the greatest depth cannot be less than 37 feet.

Obviously, the volumes of the elements "b," "c," "d" and "e," which are very large, come also within the laws of hydraulics and the dominion of the single concave. Therefore, the channel can be really made much wider and deeper than the normal one at A-B.

The volume of the normal section, A-B, plus all the other elements, following the continuous concave, must vanquish and pass the site of the Ninan bar.

Erosive Effects Below the Ninan Bar.

To obtain a graphic expression of what the volume of the normal section, A-B, alone must do further down stream, its waters being still within the control of the single concave and undivertible, this section may be imposed on a section, G-H, taken when the ebb tide now begins to spill around Hoogli Point.

Such a diagram shows the erosive ability of the volumes "a" and "f." The real effect of all the elements must be more. Comparing the normal section, A-B, with that of the present eastern gut, it is noted that the end area below the 18 foot plane in the first is nearly three times greater than in the second. A contention, therefore, that the eastern gut now carries all the ebb is manifestly without basis.

Below the Ninan the ebb, to maintain a bettered channel, has work to do. The flood tide continuing to cross from the western gut to the concave opposite Shipgang Point, which is unchanged by the project, will pour sand into the flank then as now. But as the ebb now carries off this same daily contribution, when reinforced it will certainly not fail to do so.

The Muckraputty Sands split the river, and the widening and deepening of the eastern gut necessitates the erosion of the east-

ern side of this deposit, and the removal longitudinally of the eroded sand. This action will be best secured when the annual freshet dominates the tides. Then, when the Fulta cut is opened, the concave being unyielding, the river's erosive power and sand carrying capacity greatest, the freshet will perform the work of erosion desired, so thoroughly that from Fisherman's Reach to Hoogli Point the recurring tides will find a self-maintainable, broad and unvexed channel, the making of which has not interfered for a moment with navigation. It is beyond question that the freshet will carry a wider and deeper channel than that of the section A-B to the present point of spill, G-H, and that the tides undiverted by Fulta Point will occupy and defend its enlarged, dredge and freshet made channel.

The James-and-Mary Bar.

The crest line of this famous bar may be likened to a butcher's hook. The Muckraputty Sands form the shank. The left hook bars the ebb and the eastern gut, the right hook bars the flood tide and the western gut and approach. The tracks across the eastern hook are the navigated paths. It is very rarely that a deep track opens up through the western crest.

It is easier to make a good thing better than to make a bad thing good. Previous projects have all essayed to make the bad route best by blocking straightway the only usable course, without a line of care for the travail of the shipping of Calcutta.

Is it not a more reasonable procedure to better what is, when such can be done without interference with that sensitive organism —commerce?

By the removal of the Fulta Point and the advancing of the Damudar bank, there will have been brought past Ninan, to the point of spill around Hoogli Point, the volumes of the elements heretofore referred to by the letters "a," "b," "c," "d," "e," together with "g," the latter being the tidal volume between the Ninan and Hoogli Point, less those portions of each which flow over the Muckraputty Sands and through the western gut into the main river. The action and behavior of the water along the navigated tracks, at and below the Point, may be determined with certainty by graphic analysis and confirmed by a working model.

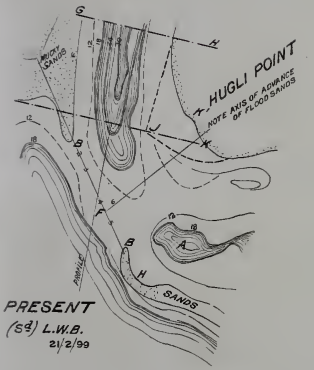
It is to be noted, first, that just below the Point the Hoogli has an under width. To remedy this, the long single concave is merged into a tangent which curves to the left in 6 feet of water south of the Point and joins the left bank. The angle at which the Hoogli and Rupnarain waters join is not to be changed by this tangent.

Western Society of Engineers.
Vol. V. No. 5.—Fig. 4.
Bates—Hugli River—Proposed Deep Water Approach to Calcutta

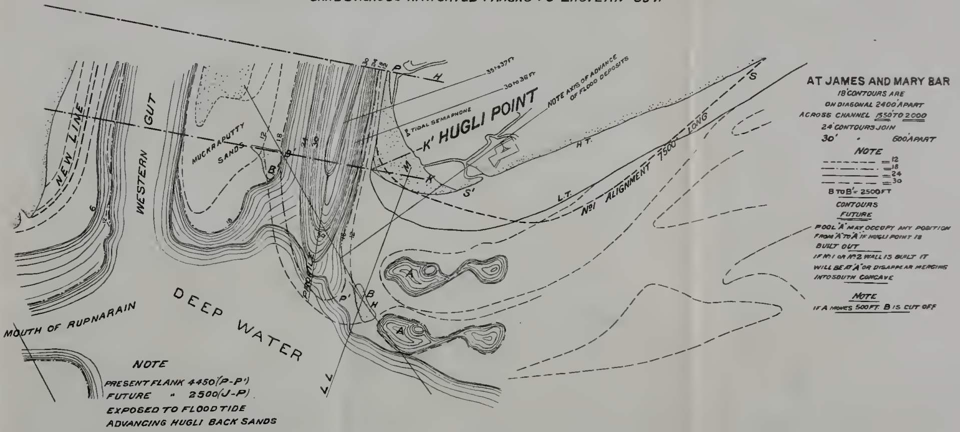
CONTOUR SKETCHES

TO ILLUSTRATE EFFECT OF REMOVAL OF FULTA POINT AND OF DUMADAR AND HUGLI POINT WALLS, ON NINAN AND JAMES AND MARY BARS, ESPECIALLY THE RESULT OF EXTENDING CONCAVE BYOND PRESENT POINT OF SPILL, ON CHANNEL BACK OF HUGLI SANDS, AND THE ADVANCE OF HUGLI SANDS ACROSS NAVIGATED TRACKS TO EASTERN GUT.

No. 1



No. 2



The effect of this tangent prolongation is to carry the point of spill south of the present one. Consequently, the deep contours of the ebb channel cannot begin to run out until the new turning point is reached and passed.

The end area of the present ebb spill conserved is shown by the triangle on section I-J-K (Figure 4) measuring 12,180 square feet at high tide. It constitutes obviously a valuable factor. Manifestly also, the bank J-S would lead the flood tide to move its pool A, further out.

In analyzing the behavior of the down stream currents one may allow that only the volume of the normal section is to be brought to the new point of spill where the 18 foot, 24 foot, and 30 foot contours are respectively 1,550, 1,030, and 800 feet apart and 37 feet maximum depth. Cross section I-J-K is taken through the new Hoogli Point (Figure 4).

The normal section is carried full to this place 1,950 feet beyond the previous point of spill. When imposed on section I-J-K it shows the erosion which must transpire on the east side of the Muckraputty Sands, also the enhanced volume, depth and width of the scouring tide. Below the 18 foot plane the present end area is but 1,950 square feet, while the new channel will measure at least 18,250 square feet.

Run-Out of Contours Below Point of Spill.

An inspection shows that when depths begin to run out they do so at the rate of about 1 to 100 in the eastern gut. At this section, I-J-K, of the present channel, both the 24 foot and 30 foot contours have run out, and the area below 18 feet has run down to 1,950 square feet, which disappears 300 feet farther out. If a similar rate of run-out is allowed for the new contours (a very conservative allowance when the greater volumes are considered) then 18,250 feet will run down to 13,800 in 1,950 feet, and 13,800 feet will run down to 11,850 in 800 feet more. Thus there must be 11,850 square feet of end area 2,750 feet beyond the new point which is below the 18 foot plane.

But no such distance is needed to obliterate the James-and-Mary bar, so far as navigation is concerned.

Sketch No. 1 (Figure 4) shows the new contours, and No. 2 shows those of the chart inspected.

On sketch No. 2 is noted the axis of the bar and the line of growth of the flood-borne sand of the back of Hoogli from B toward B[1].

On sketch No. 1, this axis, instead of running along the bar crest, is shown to meet an 18 foot channel 2,500 feet wide and a 24 foot channel 900 feet wide and 30 feet deep in the center.

Hence, when the growing spit B (as a result of flood tide action in the low water season) seeks to encroach on the navigable channel it must meet the ebb of the dimensions quoted.

In order to illustrate this, a section is shown along the crest line D-B[1] using for soundings the published depths of Jan. 30, 1899, in the various tracks. On this section the contours of sketch No. 1 are platted, also a line showing an extra bad bar condition (7 to 8 feet).

This section is along the line of growth of the spit B when pushed forward by the flood, and discloses the difficulty it must experience to advance under the new conditions.

The Hoogli ebb sweeping past the new point will curve down stream farther out than it now does, and the part which now spills into pool A will then impinge directly on spit B. As a result of the deposit of sand below the new points and the position of the wall J-S, pool A, both in so far as it is made by flood and ebb, must move out to some position A[1]. Whatever distance south it moves, it will by the same amount reduce spit B and will obliterate it altogether when it moves 500 feet, which it should certainly do. Such results by the expected movement of pool A are not vital, but deserving of consideration, as showing how the new conditions all work to defend the new fairway against such attacks as now raise the crest of the eastern hook of the James-and-Mary bar during the low water season.

The navigable fairway thus created may be from 1,500 to 2,000 feet wide and in the deepest part should be 23 to 24 feet deep at low tide.

In another view the present tracks into the eastern gut are exposed on the flank from P to P_1, a distance of 4,450 feet to the deposits of the flood. The exposed flank of the new fairway is but 2,500 feet long, and the new channel has much more self-protecting power owing to its greater width, depth and volume.

The crest of what is left of the James-and-Mary bar must then be 600 to 700 feet further out than now. This is demonstrated by the longitudinal profile which shows how, beginning at the present commencement point of spill, the contours of the present gut run out, also the long exposed flank over which the flood may carry sand to be picked up by the ebb in part and dropped on the spit and bar. It indicates the erosion due to the new channel, whose contours cannot begin to run out until the new point is passed. What sand the flood tide spills over the shortened flank would be then promptly carried within the powerful field of the main channel currents and hurried away. The new crest will doubtless fluctuate, but its limits will be from 18 to 30 instead of from 7 to 18,

and the fairway will be wide. The margin for navigation is so large that the new point may be considerably rounded. The propagation of the tide around the corner will then be easier.

While the major portion of the flood tide due to its direction, momentum, and the indraft of the Rupnarain basin will take the western gut, it is certain that a larger amount than now will go up the eastern gut, and this, too, will be beneficial. It is fortunate that the Rupnarain comes in just at the place it does to prevent any undue impinging on the south bank at Gowanhalli.

The conclusion of this synopsis of a graphic analysis is that as a result of all the forces and the new conditions the James-and-Mary bar, as a menace to an 18 foot channel, will cease to exist at the entrance to the eastern channel, though the James-and-Mary at the upper end of the sands will bar probably more effectually than now the western gut.

Execution.

The execution of the works concerned in this project has only become possible economically by the development by the writer of the powerful hydraulic suction and distance discharging dredges now available. By this system the maximum effective horse power can be concentrated upon a given work at the minimum outlay of time and labor. The large dredge plant, recently designed and built by the writer for the Russian government, has a recorded capacity of from 4,000 cubic yards per hour, when handling blue clay at St. Petersburg, to 9,000 cubic yards per hour of light sand near Antwerp.

The cutting away of Fulta Point involves the removal of a triangular piece of country measuring about three miles on the base and three-fourths of a mile deep at the point. This can be best done by dredges, which would be specially designed for the purpose.

Procedure at Fulta and Hoogli Points.

The method of procedure would be to acquire the land shown on the chart, together with a rectangle of the same length and width as the triangle to be cut away, and consequently of double the area. The total amount of land required would be about 2,000 acres.

An embankment being first thrown up by native labor around the whole area, which is generally below high water of spring tides, water would be admitted from the river and also pumped on it by the dredges, which would then, working inside, excavate the triangular portion, depositing the material dredged on the rectangle prepared for the purpose.

A shell would be left until the last, which would be removed at

a favorable opportunity in the freshet season after Hoogli Point had been extended southward. A channel at least six or seven hundred feet wide would at once be opened under the new concave banks similar in section to the normal one (A–B) in Fisherman's Reach. The rest of the wall of earth defining the old Fulta Point would be subsequently removed, as by the advance of the training walls on the opposite bank the normal width of the river was effected.

The dredge plants could always work inside the Fulta shell and the various training banks; consequently their operations would not interfere with navigation nor be impeded by the currents of the stream, however strong they might be.

Construction of Training Banks.

The approximate alignment is shown by a continuous line on either side of the river. Only such parts of this alignment need be the site of training banks as it is decided are requisite to obtain the benefits sought for navigation.

The Hoogli Point extension would advisedly be a reclamation. The works either side the mouth of the Damudar would terminate at Dhaja and Shipgang Points, a length measuring, with those defining the outlet of the Damudar, 36,600 feet.

The section north of the Damudar mouth should be built before that on the south.

Moyapur Bar.

Referring to Figure 1, the new banks at the Achipur and Hirangunj Sands should be divided into sections and constructed in the following order:

Hirangunj Training Bank.

1st. The central section defined by a full line.

2nd. The section between No. 3 crossing marks and the upper end of the central section would be best put in, a third of the distance at a time, commencing at the lower end.

3rd. The lower section between Katakkali Hirapur Khal and Dukinpara Khal should be built in connection with a future Royapur bar improvement after the Brul sandbank had been completed.

Achipur Training Bank.

Subsequent to the execution of sections No. 1 and No. 2 of the Hirangunj bank, the Achipur should be constructed in two successive sections. If the upper section is made first, it will render easier the putting in of the lower one.

Brul Training Bank.

The Royapur crossing will be benefited by the Hirangunj bank, because a larger volume of both flood and ebb and freshet will thereby be caused to flow through the tracks of the present crossing. The incident erosion will probably be sufficient for the needs of navigation. But the normalizing of the great expansion at the Brul Sands will be of sufficient benefit to justify the construction of the Brul bank from the Royapur tide gauge site to Chungra Khal after the obstructions at Fulta, Ninan and Hoogli Point and the Moyapur have been removed.

Though the works required for the improvement of the Moyapur and Royapur crossings are of less magnitude than those prescribed for the removal of the Ninan and James-and-Mary bars, those near the Moyapur especially can hardly at once be made so complete in their effects. An inspection of the chart shows that the deep channels under the concave banks overlap each other, and the diagram shows that the low tide width is so great that it leaves room for the mid-river bar to form. The aim must be by the progressive construction of the sections of the Hirangunj and Achipur banks to bring the 18 feet contours closer and closer so that they may be made ultimately to coincide.

If, before the proper low tide width is realized, they do not make the deep channels quite join, they will yet reduce the dividing shoal to such a narrow width that a Fulta Point dredger can work on it along and not athwart the axis. In a single tide such plant as would be available could completely remove the dividing shoal, leaving a channel probably a thousand feet in width which would require for maintenance very little annual dredging.

The Writer's Proposals for the Improvement of the Approach to Calcutta, may, therefore, finally be Summarized as Follows:

1st. That a proper bank alignment and ratios of expansion be calculated and finally located and adopted in accordance with the principles enunciated and with the preliminary location sketched on the plans for,—

(a) The Hoogli river from Calcutta to the Rupnarain river.

(b) The Damudar river at its lower end.

(c) The Rupnarain river from the mouth to the upper end of the basin (after survey and due consideration of data obtained).

2d. That Fulta Point be removed, so that the resultant bank shall form a continuous concave from the vicinity of Fisherman's Point anchorage to Hoogli Point.

This excision shall include rectification of the banks near the focus leading mark of the James-and-Mary bank tracks. Excavated material is to be distributed on a tract adjacent to the point and indicated on Figure 1.

3d. That Hoogli Point be filled out to lines to be definitely established, but substantially those indicated on plan.

4th. That combined pile, fascine and earth embankments or walls of suitable design be constructed opposite Fulta Point, defining the outlet of the Damudar river and a new right bank to the Hoogli river adjacent thereto, as indicated in the foregoing text.

5th. That similar new works be constructed at the Achipur and Hirangunj Sands to be ultimately carried to a tapering connection with the concaves on either side of the Moyapur crossing, as set forth.

6th. That a similar construction be made at the Brul Sands wherever it becomes desirable to improve the Royapur crossing and to normalize the Brul expansion.

7th. That all of the excavation, filling and embanking, except certain preparatory work performed by native labor, shall be done by a specially designed hydraulic dredging plant, the dredgers to be adapted, also, to work in the lower river below Diamond Harbour.

In sequence to the writer's visit, and report, the Calcutta Port Commissioners sent a delegation to Antwerp to witness the trials of the Russian Government machines. A dredge ordered by them, and constructed by Sir Wm. G. Armstrong, Whitworth & Co., is en route to India, and a survey of the Rupnarain, and model experiments, are in progress.

Robt. J. McClure

ROBERT JOHN McCLURE, M. W. S. E.*

Died March 16, 1899.

Born at Lisburn, County Antrim, Ireland, April 23, 1841. Died at Miami, Florida, at the Royal Palm Hotel, March 16, 1899.

His father, Adam McClure, was born at Lisburn in 1797, and belonged to the Galloway (Scotland) family of that name; one of his ancestors came to Ireland from Scotland at the time of the "Plantation of Ulster" in 1608. Robert John McClure was the fifth son by his second marriage.

His mother was Margaret Wilson. She belonged to a Scotch family of that name which had emigrated to Ireland in the seventeenth century.

Mr. McClure had extraordinary opportunities for education. A private tutor prepared him for Queen's College, Belfast, which he entered in 1856 with the view of taking out his diploma as civil engineer. His progress in mathematics was very great, and toward the end of his second year, within a month or two of the examination and without any special preparation, he was urged to compete for a place in the Royal Artillery or Royal Engineers. The twelve passing the highest examinations were appointed cadets in the Royal Engineers, and the remaining successful candidates in the Royal Artillery. He succeeded in taking seventh place, and proceeded at once to the Royal Engineering College at Addiscombe.

He graduated, taking second place in his class, and went to the Royal Engineer Depot at Chatham, where he remained until assigned to duty at Devonport, November 1, 1863.

He was at this time considered the first mathematician in the engineer corps, and was spontaneously promised an appointment which would have given an opportunity of distinguishing himself. He was to have been sent to the continent of Europe to join a select body of engineers from France, Germany and Russia to redetermine the latitude of certain places with the view of solving the question whether the earth's poles are fixed. At the last moment he was passed over, owing to the influence of persons in high places, and the appointment given to another.

He immediately sent in his resignation to the Horse Guards, notwithstanding the strenuous dissuasion of his colonel, and left England in December, 1863.

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*Memoir prepared by Emil Gerber, E. J. Blake and John E. Blunt.

He came to the United States in 1864 and enlisted in the Northern army, as a private in Company K in the First New Jersey Cavalry, regiment of volunteers, February 1, 1864, to serve three years, and was mustered out with the company, as a private, July 24, 1865, at Vienna, Virginia.

During the period of his enlistment he appears to have served with the company, except from some time in November or December, 1864, to some time in May or June, 1865, when on detached duty with the engineer brigade of the Army of the Potomac. At the time of his enlistment his occupation was that of a topographical engineer, and he saw a good deal of active service.

Shortly after the close of the civil war, Mr. McClure went to St. Louis, where he was employed by Bishop Kenrick in laying out the Bellefontaine cemetery. While on this work he lived in the house of Bishop Kenrick, for whom he always had a great affection and respect.

In the fall of 1865 Mr. McClure came to the office of Mr. Samuel S. Greeley, a civil engineer in Chicago, asking for employment. As his qualifications were entirely unknown, he was given work as chainman and rodman, and later as assistant on surveys. He was always ready to do any work in the line of business, even that of common labor. It was presently perceived that he was a man of exceptional attainments and unusual professional ability, and he was introduced to Mr. Max Hjortsberg, at that time chief engineer of the Chicago, Burlington & Quincy Railroad Company. He found here a field for his abilities, which were soon recognized by the officers of the company.

Upon the death of Mr. Hjortsberg, in 1877, Mr. McClure was appointed to succeed him as chief engineer. He held this position until 1883, when he was made consulting engineer of the entire system of railroads owned and operated by the Chicago, Burlington & Quincy Railroad Company.

For a year or two preceding his death he was occupied with the design and construction of the new bridge across the Mississippi river at Quincy, and with the changes in the line and yards required by the new terminal arrangements there.

Mr. McClure always retained his fondness for mathematical and scientific studies, and was one of the most accomplished and recondite students in these subjects. He used his mathematics as a language or means of expression, and his mind worked readily in mathematical channels.

His absorbing interest, apart from his profession, was natural philosophy or physics, both theoretical and experimental, and his reading followed these lines. He was a student and adherent of

the positive method of philosophy as expounded by August Comte, and accepted only results based upon experience.

During the years 1870–72 Mr. McClure was occupied in studies and experiments in radiant heat, the results of which were published in the Journal of the Franklin Institute, Vol. XCIV, No. 562; Vol. LXIV, November, 1872, No. 5; pages 351–359–p. 407.

As a result of these researches, Mr. McClure was led to deny what was then a commonly received hypothesis among scientific men, namely, that energy exists in two different forms—kinetic and potential—which are mutually inter-convertible. He maintained that energy exists always in but one form, and that when there was an apparent loss of kinetic energy or mass motion, the kinetic energy of the mass simply became kinetic energy of the molecules or heat.

He was a thorough expert on bridge design, and his opinion on all matters of construction was final.

Mr. McClure was not a social man in the ordinary sense of the word—meaning the making of a great many friends—although he possessed social gifts of a high order. He was absolutely democratic in his friendships, choosing his friends for the traits of character which interested and attracted him, and never for their social or business position. He was always reserved and self-contained, having in himself enough for interest and occupation without going outside, and did not need better company than a book or his own thoughts.

He was fond of French literature, especially the essays of Montaigne, and the plays of Moliere. With the latter he was very familiar, reading them frequently, and often quoting from them.

Mr. McClure enjoyed the best music, was familiar with the standard oratorios and operas, and knew the symphonies of Beethoven and Mozart almost by heart.

He had a keen enjoyment of humor, and his mind was a storehouse of good things in literature and philosophy, which made his conversation with his familiars a matter of the highest enjoyment.

Mr. McClure rests now in the cemetery at Quincy, just below the soldiers' monument, and overlooking the noble sweep of the great river, whose spanning by the fine steel bridge there, was his last work in life.

His friends will always cherish the memory of this helpful, noble, modest gentleman.

Mr. McClure was elected a member of the American Society of Civil Engineers October 6, 1886, and resigned December 3, 1895, and was, also, for many years a member of the American Institute of Mining Engineers. He was a member of the Western Society of Engineers from April 11, 1870, until the time of his death.

Chicago, September 26, 1900.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING, September 6, 1900.

A regular meeting of the Society was held in its hall at 8 o'clock Wednesday evening, Sept. 6, 1900. In the absence of a presiding officer the Secretary called the meeting to order and Mr. W. J. Karner was elected chairman, pro tem.

As the minutes of the previous meeting were printed in the JOURNAL, a motion was made and carried that the reading of them be dispensed with.

The Secretary reported for the Board of Direction, the receipt of applications for active membership from Walter A. Shaw and Henry Fox.

There being no committee reports for presentation the chair called for any special business, whereupon Mr. J. H. Warder made brief mention of the delightful visit down the Chicago drainage canal to the controlling works at Lockport, Illinois, on Saturday, June 30, 1900, and moved that a vote of thanks be extended to the trustees of the Chicago Sanitary District, the Atchison, Topeka & Santa Fe Railway Co., and to the Lydon & Drews Company, for courtesies in transporting and taking care of the Society on that occasion.

The motion was seconded and carried unanimously.

The Chair announced the paper for the evening as being on "The Efficiency of Small Electric Lighting Plants," prepared by Professor B. V. Swenson and A. W. Richter, of the University of Wisconsin, and introduced Professor B. V. Swenson, who made a general statement regarding the subject and then proceeded to read the paper. Lantern slide views of diagrams were thrown on the screen and of these Professor Swenson made verbal explanations. At the conclusion of the paper, the discussion was opened by Mr. J. W. Mabbs, in which Professor Swenson, Messrs. J. S. Stephens, Arthur Franzen, W. S. Love and others took part.

Before the meeting adjourned, Mr. J. H. Warder moved a vote of thanks to Professors Swenson and Richter for the able paper just read.

The motion was seconded and heartily carried.

SPECIAL MEETING, September 19, 1900.

A special meeting of the Society was held in its hall at 8 o'clock Wednesday evening, Sept. 19, 1900. President A. V. Powell occupied the Chair and presented Mr. E. Lee Heidenreich, who had prepared a supplement to the paper on "Monier Constructions," which he read before the Society on June 6th, last. Copies of the supplemental paper having been previously sent out to all members of the Society, Mr. Heidenreich enlarged only on some of the more significant points in the paper, and the subject was left for discussion.

Mr. H. P. Boardman read a brief statement of questions regarding concrete, to which Mr. Heidenreich made response.

The Chair then announced a paper by Mr. L. K. Sherman on "The Condition of Water and Power Development in Southern California." In the absence of Mr. Sherman, Mr. J. H. Warder read the paper. A number of lantern slide illustrations accompanied the reading, all of which proved interesting. The paper appears in this (October) issue of the JOURNAL of this Society.

The meeting adjourned.

REGULAR MEETING, October 3, 1900.

A regular meeting of the Society was held at 8 o'clock, on Wednesday evening October 3, 1900, President A. V. Powell in the Chair, and 41 members and guests present.

The Secretary read the minutes of the last regular meeting, and reported for the Board of Direction, as follows: The election to Active Membership of Walter Adams Shaw, Harry L. Millerd, Henry Fox; and to Associate Membership, John T. Corbett, Charles Brockway Gibson. Robbins Yale Maxon was transferred from Junior to Active Membership. Application for Junior Membership was received from Edward

H. Rodgers, and referred to Membership Committee. G. L. Clausen was, on request, after compliance with the requirements of the Board, reinstated to Active Membership.

The Secretary presented a memorial, prepared by Messrs. Emil Gerber, E. J. Blake and John E. Blunt, on the late Robert J. McClure, which appears in full in this issue of the JOURNAL.

The Chair announced the death of Associate Member John H. Esson, which occurred August 23, 1900, and of W. T. Casgrain, Active Member, which occurred on September 28, 1900.

Mr. W. H. Finley moved that the President appoint committees to prepare suitable resolutions in these two cases. The motion was put and carried.

The next order of business was the reading of papers, and the Chair introduced Mr. J. W. Schaub, whose paper on "Proposed Specifications for Steel Railroad Bridges" was announced for the meeting's consideration. Advanced copies of this paper had been furnished the members several weeks previous. Mr. Schaub said in part: "In presenting this paper, I have only gathered together what observations I could make from that which has been said and written during the last two years. * * * I will only take up such parts of it as refer to the experiments and the formula which I have written on the blackboard." After Mr. Schaub's experiments with a paper model of a girder, and explanation of the formula, the Chair called upon Mr. Horace E. Horton, who read a written discussion on the topic.

Mr. Ralph Modjeski also presented a written discussion and enlarged on it verbally. The general subject was commented upon, Mr. Schaub replying to the written discussions.

Mr. Condron referred to the physical difficulties that attend punching holes in varying thicknesses of material, etc., and then presented a diagram of specifications by the aid of a lantern slide, taking up several points in Mr. Schaub's paper for consideration, which was discussed at considerable length.

Mr. Goldmark made extended remarks on the topic of "Specifications for Materials," which were interesting, as coming from his observation and experience.

Mr. G. N. Linday then read a written statement on the subject, which was followed by further discussion, participated in by Messrs. Horton, Schaub, Modjeski, Finley, Condron, Goldmark and Boardman.

The Chair referred to the passing of the evening, and suggested prolongation of the discussion.

Mr. Finley moved that it be continued at the next meeting. The motion was carried, and the meeting adjourned. NELSON L. LITTEN,
Secretary.

EXCURSION ON DRAINAGE CANAL.

On June 30 the society gave a very enjoyable excursion to its members, down the drainage canal from Chicago, the objective point being the controlling works at Lockport. At 1 o'clock three boats, furnished by courtesy of the trustees of the sanitary district, and the Lydon & Drews Co., loaded with excursionists, left the dock at Adams street. The weather was perfect for the purpose, and the party left in high spirits which did not flag during the entire afternoon. On the way down, the various points of especial engineering interest were pointed out Messrs Isham Randolph. Thos. T Johnston, L. E. Cooley, Ossian Guthrie and others identified with the conception and execution of the great drainage channel, were of the party. While not engaged in gazing at the wonders of the channel, the party addressed itself to a discussion of the excellent lunch which had been provided, and quartette music still further enlivened the long journey. Arrived at the controlling works the party was treated to repeated operations of the famous bear trap dam After plenty of time had been given for inspection of the dam and the great gates, the party was put aboard the boats again and taken a short distance up stream, where change was made to a special Atchison, Topeka & Santa Fe train, provided by the courtesy of the officers of that company, that had been held in readiness, which made a quick run back to Chicago This excursion, which was in charge of Mr. J. J. Reynolds, chairman of committee of arrangements was generally voted to be a most enjoyable and interesting outing.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL we have received the following gifts from the donors named:

New York R. R. Commissioners, Report of Competitive Tests of Street Car Brakes, 1899.
American Society of Civil Engineers, Transactions June, 190c, Vol. XLIII.
New England Cotton Manufacturers Association, Transactions, No. 68.
Mining Reporter, Denver. Sullivan's New Hydraulics.
Board of Public Works, Grand Rapids, 27th Annual Report, April 30, 1900.
U. S. Government, 14th Annual Report of the Commissioners of Labor, 1899.
Geo. S. Webster, 1st Annual Message of S. H. Ashbridge, Mayor, City of Philadelphia: Annual Report Department of Public Works, Philadelphia, 1899.
Merchants' Association of New York, The Water Supply of the City of New York.
American Society of Heating and Ventilating Engineers, Transactions, Vol. V.
Harrison Safety Boiler Works, Catalogue Cochrane Heaters.
F. G. Ewald, Report Railroad and Warehouse Commission, 1895, 1896, 1897.
International Congress of Navigation, 54 Pamphlets.
State Board of Health, Michigan, 26th Annual Report, Year Ending June 30, 1898.
Armour Institute of Technology, Year Book 1900-1901.
Iowa Railroad Commission, Report 1899.
Institution of Civil Engineers, Minutes of Proceedings, Vol. CXLI.
Master Car Builders' Association, Report 34th Annual Convention, 1900.
E. E. R. Tratman, Two Special Consular Reports: Uses of Wood Pulp and American Coal.
B. J. Wheeler, Supt. of Streets, Boston, Mass., Annual Report Street Department, Boston, Mass., 1899.
Samuel Colvin, State Geologist, Iowa, Tenth Geological Survey, Iowa, Annual Report, 1899.
Arthur N. Talbot, University of Illinois, Pamphlet, "Uniform Chord Length Method for the Railway Transitional Spiral."
Institution of Mechanical Engineers, London, Eng., Nos. 2 and 3. Proceedings April and June, 1900.
Institution of Naval Architects, London, Eng. Vol XLII. Transactions, 1900.
American Institute of Mining Engineers. Vol. XXIX. Transactions, 1900.
University of Wisconsin, Engineering Department. The Chemical Engineer.
University of Wisconsin, Engineering Department. Recently Improved Methods of Sewage Disposal.

BY PURCHASE.

The Century Atlas of the World.

NEW EXCHANGES.

Royal Institute of Great Britain, Proceedings. London, Eng.
Staffordshire Iron and Steel Institute, Proceedings. Brierley Hill, Eng.
Public Health Engineer, London, Weekly.
The British Architect, London, Weekly.

Journal of the Western Society of Engineers.

VOL. V. DECEMBER, 1900 NO. 6.

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SOME PRINCIPLES CONTROLLING THE DEPOSITION OF ORES.

By Prof. C. R. Van Hise.

Read June 13, 1900.

I would hardly have ventured to talk on the subject of ore deposits to you, if I had not approached the subject from a different point of view from the majority of men who have considered it. The point of view from which the subject of ore deposits has been most frequently considered has been that of a study of ore deposits themselves. A geologist or mining engineer has studied this or that ore deposit, or a number of ore deposits in different districts; and has then generalized concerning the ore deposits of other districts, and perhaps of the world. I have also considered the subject of ore deposits to some extent from that point of view; but if I had done this only, I would not have ventured to give a general address upon the subject.

Some years ago I took up the question of the alterations of rocks; the alterations of all rocks by all processes. In treating this subject it became necessary for me to consider somewhat fully underground water; the principles which control its flow; the manner in which it works; the results which it accomplishes. After I had reached certain conclusions upon that general subject it seemed to me that the deposition of most ores was a special case falling under the general principles controlling the work of underground water. Therefore it is from the point of view of the circulation and work of underground water that I wish to consider the subject of ore deposits tonight. However, I cannot go into the subject fully, and will be obliged to ask those of you who are especially interested in it to refer to my more extended paper found in Vol. XXX of the Transactions of the American Institute of Mining Engineers.

There are three great classes of ore deposits: (1) those which are produced by igneous processes; (2) those which are produced by the direct processes of sedimentation; (3) those which are produced by the work of underground water. The last class is by far

the largest, and it is the only one which I shall consider this evening.

My first, then, and my fundamental, premise is: *That the most important class of ore deposits is the result of the work of underground water.* This premise I shall not attempt to prove; but because it is accepted by most geologists and by most mining engineers shall use it as a starting point.

My second fundamental premise is: *Ore deposits are derived from the outer crust of the earth—from that part of the crust of the earth which I have called the zone of fracture.** There has been much discussion as to whether ore deposits are produced by descending waters, lateral moving waters, or ascending waters. One of the most comprehensive papers which has been presented upon this subject was by Posepny.† In this paper Posepny holds that the original source of the metals of practically all the ore deposits of the class produced by underground water, is the Barysphere (heavy-sphere); and therefore that the metals come from very far below the surface of the earth. The water in some mysterious way came from this heavy-sphere,—presumably very deep-seated. The water rising from the Barysphere, where the rocks are supposed by some to contain more metalliferous material than near the surface, brought the metals of the ore deposits to their present positions. This view has been presented at great length by Posepny, and ably argued; and he has had many disciples. Now it seems to me that the well established principles of physics absolutely disprove this hypothesis; and it further seems to me that observed geological phenomena also disprove it.

I have elsewhere‡ divided the outer crust of the earth into zones, in descending order as follows: a zone of fracture, a zone of combined fracture and flowage, and a zone of flowage.

Now we will suppose that the crushing strength of the strongest rock is such that at a depth of twenty thousand meters below the surface the weight of the superincumbent rock (less the floating effect of underground water) is as great as the crushing strength of the rock. We will suppose that such a rock as the Berlin granite of Wisconsin, the strongest rock yet tested, having a crushing strength of 47,674 pounds per square inch, extends from the surface to an indefinite depth.* We will further suppose that in some

* Principles of North American pre-Cambrian geology, by C. R. Van Hise: Sixteenth Ann. Rept. U. S. Geol. Surv., 1894-95, Pt. 1, p. 589.

† The genesis of the ore deposits, by F. Posepny: Trans. Am. Inst. Min. Engineers, vol. xxiii, 1894, pp. 197-369.

‡ Principles of North American pre Cambrian geology, by C. R. Van Hise: Sixteenth Ann. Rept. U. S. Geol. Surv., 1894-95, Pt. 1, p. 589.

way openings of some kind, say large cracks, are produced at the depth where the rock is under weight as great as its crushing strength. What would happen? You engineers know very well the rock would be crushed and the openings would close. Therefore at a depth of more than 20,000 meters below the surface of the earth, where the weight of the superincumbent rock is greater than the strongest rocks, if it be supposed that cracks of a considerable size could be formed, the pressure would crush the rocks and close the cracks. But the crushing strength of the great majority of the strong rocks does not exceed one-half that of the Berlin granite. Moreover, rocks at considerable depth are at higher temperatures than normal, and this probably weakens them. Upon physical grounds we are prohibited from supposing that there are cracks and crevices of considerable size at more than a very moderate distance below the surface of the earth. But this conclusion does not rest upon physical principles alone. I have shown that there is another way besides crushing by which rocks are readjusted to deforming stresses.† If the movement be slow and the temperature that of moderate depth, the stress does not need to accumulate so that it shall be greater than the crushing strength of the rocks. Under such conditions, long before the crushing strength is reached, the contained water begins to act upon the material of the rocks and re-arranges it by continuous solution and deposition; so that it behaves as a plastic body. At all times the rock is a solid, except for the infinitesimal amount held in solution; and yet it continually adjusts itself to the deforming stresses. A great many rocks which have been thus deformed under deep-seated conditions have a laminar structure which is analogous—not exactly similar, but analogous—to the leaves of a book. To make the analogy exact it would be necessary to suppose that the leaves are welded together, i. e., held firmly by the molecular attraction between them. What has happened in the case of these laminar rocks? They have been transformed from a massive to a laminated form by recrystalization, but in many cases combined with mineral granulation and differential movements of the mineral particles. During the process of recrystalization, for each mineral particle, material is continually taken into solution on the sides where subjected to greatest stress and deposited on the edges where the stress is less, until the laminar structure is produced. The process of adjustment largely, and in many cases mainly, by continual

* Building and ornamental stones of Wisconsin, by E. R. Buckley: Bull. Wis. Geol. and Nat. Hist. Surv., No. IV, 1898, p. 390.

† Metamorphism of rocks and rock flowage, by C. R. Van Hise: Bull. Geol. Soc. Am., vol. IX, pp. 269-328. Pl. XIX.

evolution and redeposition, is rock flowage. Now rocks in which this process has taken place are found at the surface at many places. Moreover these rocks are frequently those of great strength. In many places it is certain that the amount of material which has been removed by erosion since the rocks were recrystalized is not more than 2,000, or at most 3,000 meters. Since, therefore, the process of rock flowage often takes place at much less depth than that at which rocks are crushed, it follows that large openings are not likely to exist at depths so great as above calculated for the closing of openings by crushing. It is highly probable that few openings of appreciable magnitude exist at depths so great as 10,000 meters.

Therefore, from the principles of physics and from observation, we conclude that crevices and cracks of considerable magnitude do not exist below a very moderate depth. I would not say that minute cavities filled with liquid do not exist in the zone of rock flowage; I would not say that very small openings filled with gases may not exist in that zone, but there is every reason to believe that such cavities are exceedingly small. And it is well known that ore deposits, in order to be of economic value, must be of considerable magnitude. Such deposits were not formed in the minute and discontinuous openings filled with gas or liquid which very possibly exist at great depth.

But let us now consider this subject from another point of view. You, as engineers, know very well that the friction of a moving liquid increases very rapidly as the size of the passage through which it moves decreases. This is true even of super-capillary tubes. It is still more true of capillary openings, and the resistance goes up very rapidly as the capillary tubes decrease in size. When the openings become so small that the molecular attractions extend from wall to wall, or the openings are sub-capillary, the resistance is so great that the flowage is practically nil.* Now it is perfectly evident that a deposit of mineral material in an opening is not the work simply of the water that occupied it at any one time. Ordinarily underground solutions of silica do not contain upon the average more than one part of silica per 100,000 parts of water, so that if an opening be filled with quartz, the most abundant of all the gangue minerals, we must suppose at least 100,000 times as much water went through the opening as there was quartz deposited. Therefore, it is perfectly clear that the material for large ore bodies can be gathered and then re-deposited only in the zone where there is vigorous circulation, and vigorous circulation is impossible in the deep-seated zone in which there are no

* Metamorphism of rocks and rock flowage, by C. R. Van Hise: Bull. Geol. Soc. Am., vol. ix, p. 272.

continuous cracks and crevices of considerable size; hence the hypothesis of the derivation of the metals of the ores from the Barysphere is untenable. Valuable ore bodies have been deposited in openings and passages of considerable size and by a vigorous underground circulation. Since the magnitude of openings and vigorous circulation are correlative with, and exist only in, the upper zone, that of fracture, the ores must have been derived from and deposited in this upper part of the crust of the earth.

If, then, we admit the fundamental premise, that the majority of ore deposits are the work of underground water, it seems to me that the conclusion cannot be escaped that the metals which are in the ore deposits are immediately derived from an upper zone, probably having a maximum depth of 10,000 meters, or seven or eight miles, in which the circulating waters are vigorous and effective.

However, I do not assert that now, nor at any time in the past, metals for ores have not been derived ultimately from a deeper source through the agency of vulcanism, the medium of transfer being the igneous rocks. We do not know how deep down the igneous rocks, which are intruded into the zone of fracture or flow out at the surface of the earth, are transformed to magma, if they have not always existed as magma. We do not know very well the process by which the igneous rocks make their way up through the solid rocks of the zone of flowage. We do know, however, that they come from a very considerable depth and take advantage of openings and cracks and crevices as soon as they reach the zone of fracture. For instance, in the Sierra Nevada, where there are various great sets of joints in the granite—vertical, inclined and horizontal—the lava coming up from below has wedged itself into these joints producing sets of parallel dikes. As these joints are utilized by the igneous rocks, so are openings of other kinds where igneous rocks intrude the zone of fracture. Igneous rocks in vast quantities, as lava, are poured out on the surface or, as tuff, fall upon it. These igneous materials undoubtedly do in many cases bear metals out of which ores are made. But in few instances are they ores as igneous rocks. Igneous rocks so rich in iron as to serve as ores have been formed on a very small scale. Vogt* holds that certain sulphide ores are produced directly by processes of differentiation of igneous rocks; but while I do not deny this, I also would not unqualifiedly assent to it. However this may be, there is fair agreement on the part of all that the great mass of the metals which come from the igneous rocks are derived from them through

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* J. H. L. Vogt: Zeitschr. fur prakt. Geol., Jan. and April, 1893; Oct., 1894; Apr., Sept. Nov., Dec., 1895.

the agency of underground water, and that the ores which are now worked by men are preponderantly concentrates from the igneous rocks, or from the sedimentary rocks, or from the two combined. But if some ores have directly solidified as magma, they do not come within the scope of the discussion tonight; for I said at the outset that only ores produced by underground water would be considered. Such ores are probably derived, for the most part, from the upper 10,000 meters of the crust of the earth.

My third premise follows directly from the considerations already given: *If the waters below the zone of fracture do not circulate vigorously, and if vigorous circulation by underground water be necessary in order that ore deposits be produced, it follows that the waters which perform this work are of meteoric origin.* They are the waters which fall from the clouds upon the earth and sink into it. I do not deny that some small part of water concerned in the production of ores may be derived from below the zone of fracture; I do not deny that the igneous rocks rising from below bring with them small amounts of water; but those amounts are insignificant, are inappreciable in quantity as compared with the vast amount of water which is necessary to do the work of ore deposition. We know to a certainty that the great mass of underground circulating waters are of meteoric origin. For instance, if a well be drilled at Chicago through the limestones and shales near the surface into the sandstone below, you know that great quantities of water issue. The water falls upon the ground far to the northwest, in central Wisconsin, where the sandstone reaches the surface. It follows this pervious formation below impervious strata, and when the impervious strata are punctured at Chicago rises to the surface through the opening. So it is with artesian wells everywhere. I repeat, *The waters which we know to be vigorously circulating are of meteoric origin, and these are the waters which have deposited the ores.*

We are now ready to pass to the fourth of my premises, viz.: *The movement of underground water is mainly due to gravitative stress.* This is, perhaps, so plain to you as engineers that it will hardly need proving; but certainly many men who have written about ore deposits have given other explanations. Why does the water rise in the artesian wells in Chicago? Simply because the level of underground water at the northwest where the sandstone is fed is at a higher elevation. The difference in elevation is only a few hundred feet; and yet the difference in the weight of the columns, or the force of gravity, is sufficient to drive the water underground through the sandstone for a hundred or more miles to Chicago, and make it rise considerably above the level of Lake Michigan. If the deformation had been such that the porous forma-

tion had somewhere been depressed nearly to the bottom of the zone of fracture, and the openings had not thereby become smaller, this in no way would have lessened the speed of circulation. It is, therefore, clear, from our knowledge of artesian wells, that a very moderate head is entirely adequate to account for an underground lateral circulation of great length, and for a vertical circulation of great depth — entirely adequate to account for it. If this be true, why should we appeal to subterranean heat or to the unknown mysterious forces at the depths as a main cause for underground circulation?

I do not deny that in some cases water is squeezed out of the rocks by orogenic movements, nor do I deny that heat produces an effect in underground circulation. We may suppose, for instance, that the water entering at one point issues at another point at the same elevation, after following a deep underground path. Suppose the water during the journey comes in contact with volcanic rocks, or suppose the water becomes warmer as the result of the normal increase in temperature with increased depth. We will suppose, for the sake of simplicity, that the temperature of the water is 0° C where it enters the ground, and at a temperature of 100° C where it issues. This is an extreme case, and beyond the facts; but it makes the illustration simple. During its journey the water expands as a result of its rise in temperature, and a unit volume of the issuing water weighs only about 96 per cent as much as does a unit volume of the entering water. The cooler or descending column contains a greater mass of water than the ascending column; it is, therefore, pulled stronger by the force of gravity; and consequently circulation takes place. The descending column falls and the ascending column rises because of the gravitative stress.

In the case of the Chicago artesian wells we have seen that the flowage is due to differential gravitative stress resulting from difference in head. In the case we have just considered, we have seen that the flowage may be due to differential gravitative stress occasioned by difference in temperature. Therefore, underground water circulation caused by gravitative stress may be initiated by difference in head or difference in temperature, or by both combined. Ordinarily difference in head and difference in temperature work together. Commonly water enters the ground at a higher level than it issues; and I think it can be shown that water which is descending is upon the average at a lower temperature than water which is ascending, although I cannot stop to fully discuss this point. Therefore, the descending column is heavier. Hence unequal gravitative stress caused by difference in head and by difference in temperature is the adequate cause to which I appeal to account for the circulation of underground water which

does multifarious kinds of geological work, a small part of which is the deposition of ores.

It is now necessary to consider in some detail the manner in which underground water moves. For a long time I have realized that if underground water had a difference in head that it might penetrate to a great depth and rise again to the surface; but I did not realize that it was not necessary to assume exceptional openings for such a circulation. I assumed that where such a circulation took place exceptionally favorable channels were available; but a recent paper by Prof. Slichter* upon the motion of groundwater showed me that this was an entirely unnecessary assump-

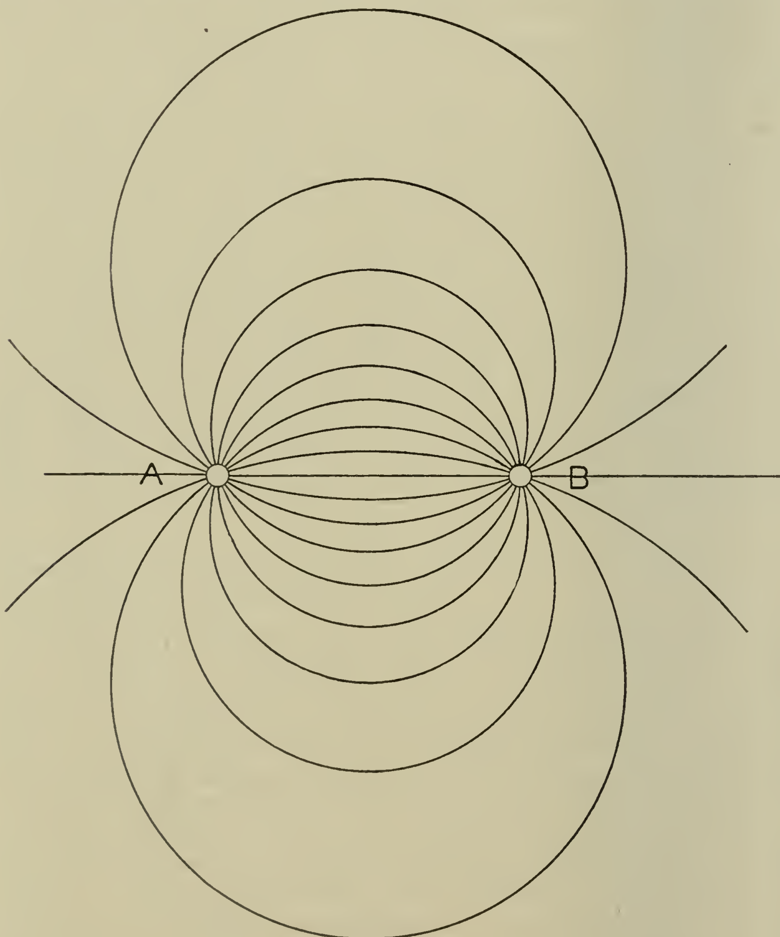

Fig. 1.

*Theoretical investigation of the motion of groundwaters, by C. S. Slichter: Nineteenth Ann. Rept. U. S. Geol. Surv., 1899, Pt. II, pp. 295–384.

tion, and gave me the additional data needed upon this point. This chart (Fig. 1) is a horizontal diagram. A represents one well and B another well, separated by a homogeneous porous medium. Into the well B, I pour water. In the well A there is no water at the outset; and the water flows from the well B to the well A through the medium. What is the path of the water? Its flowage is represented by the curved lines. Some of the water goes in a nearly direct course. Another part takes a somewhat curved course. Still other parts of the water follow a very indirect course, represented by the longer curved lines. All of the available cross section is utilized. If, for instance, this room were filled with water, and water were running in at one place in the front end of the room and were escaping at one place in the

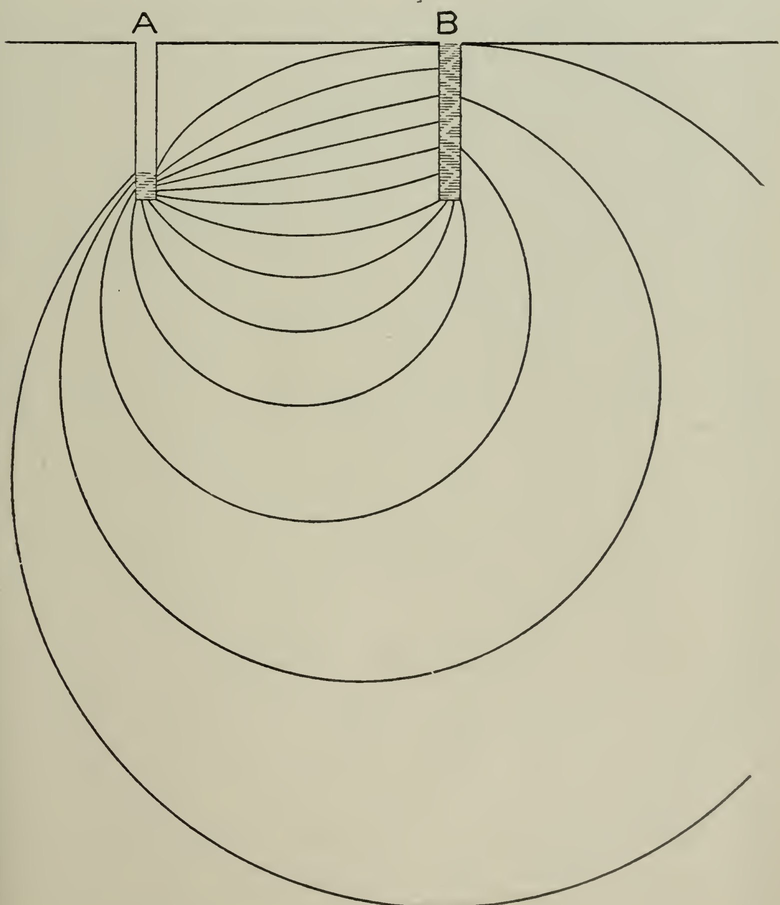

Fig. 2.

rear end of the room with equal speed; would the water simply follow the direct line between the two? You know perfectly well it would not. The entire available cross section of the room would be utilized, although the more direct course would be utilized to a greater extent than the more indirect course. This is intended to be illustrated on the chart (Fig. 1) by the lines representing the nearly direct courses being close together, and the lines representing the indirect courses being further apart.

This chart (Fig. 1) then represents the horizontal circulation. If we pass to the vertical circulation the flowage is represented by this chart (Fig. 2). The water is being poured into the well B and passes to the well A. The water follows the course of the curved lines, so that with a difference in head equal to the difference in the level of the water in the two wells, a considerable part of the water being poured into B and passing through the homogeneous porous medium to A penetrates a considerable depth, from which it raises and enters the well A. Now what will be the limit in nature of the downward search of underground water? We have already given it. Manifestly the lowest limit of effective circulation at any place is the botom of the zone of fracture at that place. The zone of flowage below is practically impervious. However, an impervious limiting stratum may exist at depths far less than the bottom of the zone of fracture. An impervious limiting stratum, perhaps a shale, may be found at a depth of 100 meters or less, or at any depth intermediate between this and the bottom of the zone of fracture for the strongest rocks. Where there are one or more pervious strata which are inclined, and above, below, and between which are impervious formations, there may be two or more nearly independent circulations. To illustrate, at Chicago the St. Peter's sandstone, the Potsdam sandstone, and even different parts of the Potsdam sandstone have more or less independent circulations. If a limiting stratum be supposed to be half way down on the chart (Fig. 2) the lines of flow above this stratum would not be as they are now but would be flatter and would be limited by the impervious rock.

Under natural conditions wherever there is an impervious rock there is a limit of some particular circulation in that direction. A limiting stratum may therefore be very near the surface, at the bottom of the zone of fracture, or at any intermediate depths; and theoretically a moderate head is sufficient to do the work of driving the water to any of these depths. Indeed, there is no escape from the conclusion that at least some circulation does occur in the deeper parts of the zone of fracture with a very moderate head. Of course in proportion as the head is great the circulation at depth is likely to be vigorous. But it may be objected that a deep circulation, while theoretically possible, must be exceedingly small in

quantity, and consequently of comparatively little account in the deposition of ores. But the consideration of the underground circulation in reference to the Chicago artesian wells (see page 438) shows that this objection has little weight. Moreover, the deeply circulating water, if less in quantity than that near the surface, takes a longer journey and is longer in contact with the rocks through which it is searching for the metals. Not only so, but it is at a higher temperature than the water at higher levels: and this also is favorable to taking mineral material in solution. And finally because it has a higher temperature it has less viscosity. While

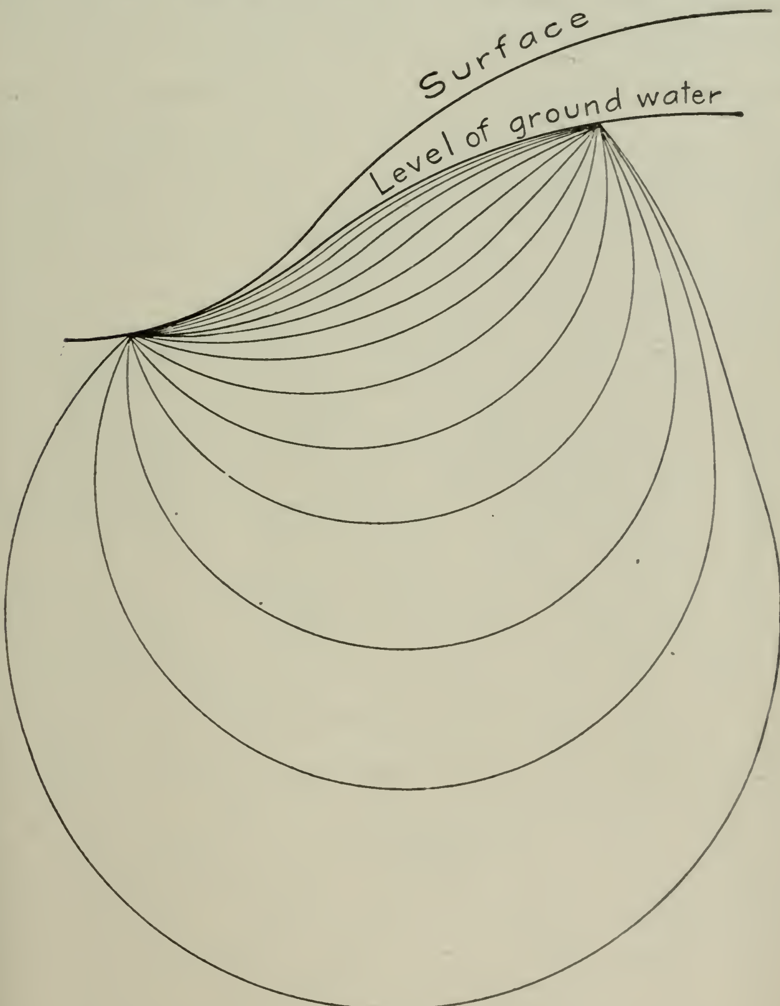

FIG 3.

the variable viscosity of water is not so very important in reference to circulation in super-capillary tubes, in capillary tubes, which constitute a very large fraction of underground openings, and especially those at considerable depth, the viscosity is important, the flowage increasing directly as the viscosity decreases. The viscosity of water at 90° C is only one-fifth as much as it is at 0° C; and therefore with a given head of water in capillary tubes if the temperature be considerably increased—and but a moderate depth is required to give considerable increase—the water moves several times as fast as it would at the surface under conditions similar in all respects save temperature. Therefore, because of these three factors, long journey, high temperature, and low viscosity, we cannot exclude the deep circulation from consideration. This circulation is indeed believed to be very important in the deposition of ores.

We are now prepared to consider the actual journey of underground water. Where water falls upon porous ground it finds innumerable openings through which it enters and begins its underground journey. This circulating water, as far as practicable, under the law of the minimum expenditure of energy, follows the paths of easiest resistance. But these are the larger openings, because resistance due to friction along the walls and within the current is very much less per unit circulation in large than in small openings. While, therefore, water enters the ground at innumerable small openings, as it goes down it more and more seeks the larger openings. Once found, it holds to them. The farther it continues its journey, the greater the proportion of the water which follows the larger openings. But if this be true, the water in its descending course is more likely to be widely dispersed and in the smaller openings; and in its upward course, more likely to be concentrated and in the larger openings.

We can now follow the course of underground water in detail, but in doing this it is necessary to consider the elements of the problem separately. It is only by passing from a simple case to the very complex one of nature that we can understand the latter. Here is a chart (Fig. 3) which shows the surface of a slope, the level of ground water, and the flowage of water in the simplest imaginable case. Below the level of ground water all the openings in the rocks, great and small, are filled with water. The rocks are saturated. In the case represented, I have supposed that all of the water enters at a single point, A; and that all of it issues at a single point, B. The curved lines represent the flowage of the water through a homogeneous porous medium. In the next chart (Fig. 4) I have supposed water to enter at three points and issue at one; and I have supposed the flowage from each point of entrance to occur just as if no water were entering anywhere else; and, therefore, the systems of flowage to be superimposed. Of

course, this is not a real case. Underground water does not diverge from a single point and converge at another point in independence of the water entering at other points. The water entering at innumerable points in vertical section and in horizontal section mutually interfere, and make the course for any given particle of water rather simple. This I have tried to represent by another chart (Fig. 5). In this chart I have supposed particles of water to enter at equal horizontal intervals, and issue at a single point. You note that the water near the crest begins its journey by almost vertical descent. In proportion as the entering water is near the valley, the horizontal component becomes more important. The water near the valley follows a comparatively shallow course;

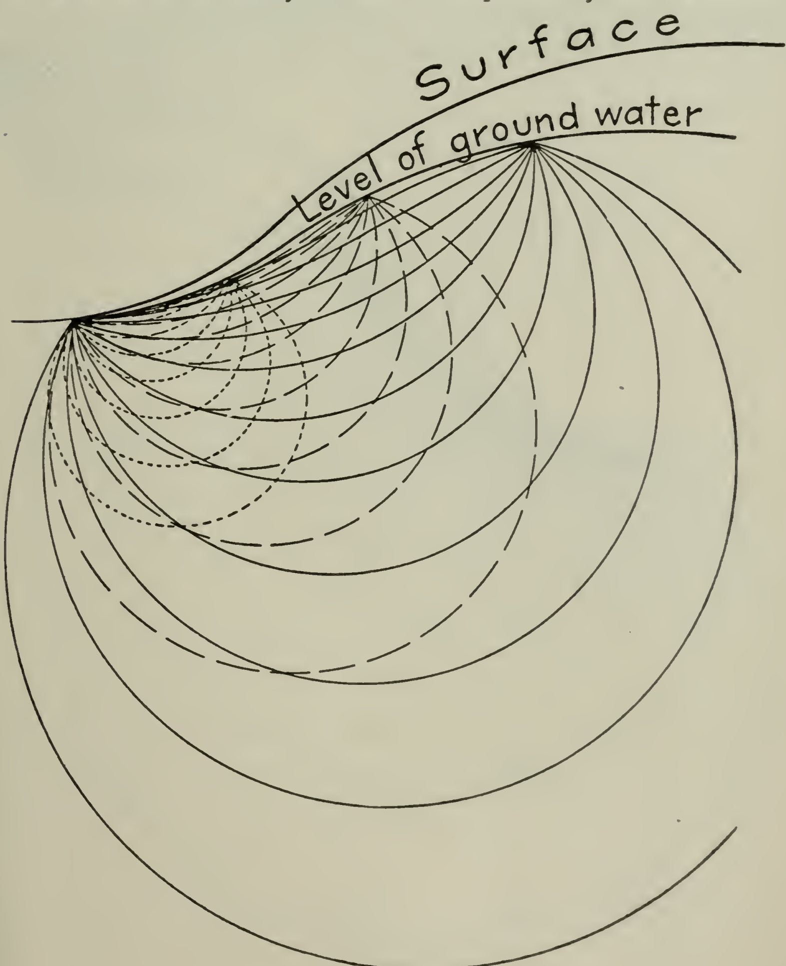

Fig. 4.

but this water uses all the available space near the surface, and consequently the water entering at the higher ground necessarily follows a long, circuitous, and deep course. The chart (Fig. 5), therefore, represents the flowage with many points of entrance and a single point of exit, where there is interference of the circulating waters.

Thus far it has been supposed that the ground is uniformly porous, like an evenly grained sandstone without joint or fracture of any kind, in which the water can go in all directions with equal ease. But absolute uniformity does not exist in nature. The openings in rocks are never of uniform size; they are never equally distributed. Suppose half way down the slope there is a vertical opening of unusual size transverse to the plane of the chart (Fig. 6), and another similar opening below the valley. If you please,

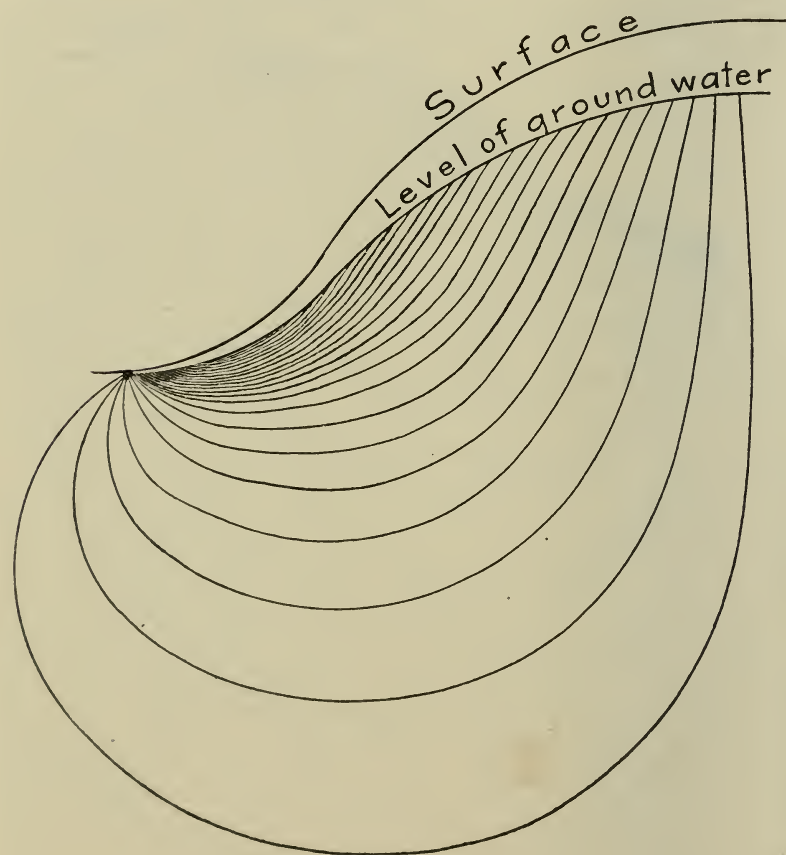

Fig. 5.

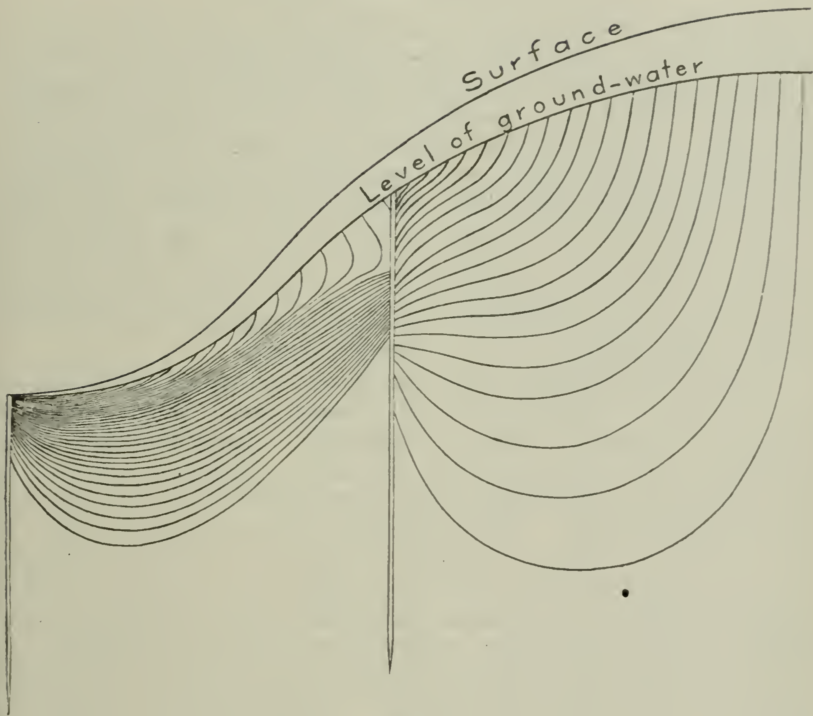

FIG. 6.

we will call them fissures. These fissures, because large openings, will be fully utilized by the underground water. We readily see that ground water will enter the higher fissure at many points and from various directions. Ordinarily it will enter the upper part while it is still descending; it will enter the central part laterally; it will have begun its ascent before it enters the lower part. Therefore, a fissure upon the middle of a slope will be very likely to receive water from above, from the side, and from below. But at a certain area of a fissure well up on the slope, the water continuously received at the upper side of the fissure will escape laterally at the lower side. This water and that entering the ground below the upper fissure will make its way to the fissure below the valley. But here the level of ground water is at the surface, consequently all the water entering this fissure will ascend quite to the surface and issue as a spring. If there be a fissure at the crest, we can see that the descending water will go a long way down; but the waters will nowhere be ascending. If there be a fissure on the slope, both descending and ascending waters will ordinarily be active; although it is, of course, recognized that in fissures thus

located the conditions may be such that the waters will ascend or descend only. If there be a fissure below a valley where the level of ground water is at the surface, the water will all be ascending, and there will be no descending water. At such places we have springs. Springs do not issue from the tops of mountains, but from slopes and valleys; most frequently the latter. Illustrating this are the Yellowstone Park springs of the Firehole river. The waters which feed the springs fall upon the crests and slopes of the mountains adjacent; on their way to the valley go deep below the surface, and at the Firehole ascend as hot springs and geysers. The water is driven by gravity due to a considerable head and the lower temperature of the descending column.

You are all doubtless aware that three theories are maintained as to the source of the waters which deposit ores. Some hold that the waters doing the work are descending; others that they enter laterally; others that they are ascending. The first is known as the descension, the second as the lateral secretion, and the third as the ascension theory. If my argument be correct as to a limit to the zone of fracture, fissures, as well as all other openings, must gradually become smaller and smaller, and finally die out altogether. Water in a fissure may descend or may ascend for a considerable distance; but it is perfectly clear that so far as fissures are concerned, except for the small amount entering the surface openings, the water must enter laterally. Consequently, if we apply the lateral-secretion theory broadly enough, we may say that all the waters which feed the fissures are lateral-secreting waters. But if we are descensionists and consider only the small upper part of a fissure on the slope—and that is what many very naturally have done, because this is the part of the fissure most easily observed—we may say that the waters which are doing the work are descending waters. Or if we are in such a district as that of the Comstock lode, in which are found great volumes of ascending water, we may say that the waters which are depositing the ores are ascending. All may be true. But in the past Sandberger held that lateral-secreting waters in the narrowest sense did all the work, and he refused to believe that ascending and descending waters were of importance; and Posepny held that ascending waters did nearly all the work, and gave small consideration to lateral-secreting and descending waters; whereas, you see with perfect clearness that each theory is incomplete. Both are needed; they supplement each other.

Passing now to the work of underground water, we find there are very great differences in the nature of the work which takes place above the level of groundwater and below the level of ground-

water. The first is called the belt of weathering; the second the belt of cementation * (see Fig. 7.) Also, there are great differences in the work which takes place in the zone of fracture, which includes both the belts of weathering and cementation, and that in the deep-lying zone, that of rock flowage.† All of these differences have a very close bearing upon some phase of ore deposition. But the subject is too complex for me to take up fully, and I shall

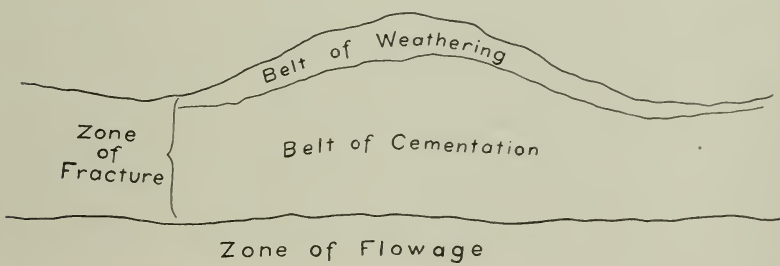

Fig. 7.

simply give the major differences in the reactions without stopping to demonstrate their correctness.‡ Above the level of groundwater, in the belt of weathering, the chemical reactions of oxidation, carbonation, hydration, and solution are the rule. The mechanical results are disintegration, softening, and decomposition of the rocks. Below the level of groundwater in the belt of cementation the chemical reactions of oxidation and carbonation are less active; but hydration occurs very extensively. Instead of solution, deposition is continually taking place. The mechanical result is that the rocks instead of being disintegrated, softened, and decomposed are hardened, the openings being cemented. Where comes the material for cementation? Why, from this belt of weathering above where solution is taking place. If the waters in the belt of weathering are continuously taking materials into solution and are continuously depositing material below, as denudation goes on these belts steadily migrate downward. The present belt of weathering not long ago geologically was in the belt of cementation. While, therefore, the belt of weathering at any given time in the past, as now, was relatively thin, it may have moved downward for thousands of feet. In many mining districts it is estimated that

*Metamorphism of rocks and rock flowage, by C. R. Van Hise: Bull. Geol. Soc. Am., vol. IX, p. 278.

†Metamorphism, cit., pp. 278–286.

‡For a fuller discussion see Metamorphism, cit., pp. 277–286.

from 1,000 to 3,000 or more meters of rock have been removed from above the present surface. All of this thickness has been in the belt of weathering; although at any one time the belt of weathering may have been but a score or few score meters in thickness. Therefore, from the belt of weathering a great and adequate amount of material may have been derived to fill the cracks and crevices of the entire belt of cementation below, although this belt may be thousands of meters thick. This process of filling cracks and crevices by deposition is the general law for the great belt of cementation below the level of groundwater, just as certainly as solution is the general law for the belt of weathering above the level of groundwater. These are the dominant processes. However, I by no means assert that deposition does not occur in the belt of weathering and that solution does not occur in the belt of cementation. Indeed, the solution of material in various places in both the belts of weathering and cementation, and the deposition of this same material, or a part of it, in the same belts at other places are very important processes.

We therefore conclude that the solution of material in the belt of weathering and the deposition of material in the belt of cementation, and the solution and deposition of material within the same belts, fills the openings in the rocks below the level of groundwater. These processes are gradually changing the soft sandstone, such as exist below the surface limestone of Chicago, into quartzite. By the same processes fractures, small and great, from minute joints to great fissures, are filled by deposition of material from underground waters. The formation of ore deposits is largely an incident of this process. The volume of material transported from the belt of weathering and deposited below in the openings of the belt of cementation, and transferred from place to place within these belts, is many million times greater than the ore deposits. The development of ores is merely an exceptional case of a widespread and most important geological process, the deposition of ores involving only a consideration of the particular materials which are of value to man. This evening I propose very briefly to discuss the source of such materials; how they are carried; why and where they are deposited. The particular case is under the general laws which control the general processes of solution and deposition.

There are a great many chemical laws which affect the process of ore deposition, and a few of them I am obliged to mention. The first law is: All the elements and compounds of nature are soluble to some extent in water. If water be placed in contact with an hundred substances, it will hold some part of every one of those substances in solution. It follows that if in the journey of

underground water it finds here and there gold or silver or lead or zinc or iron, in quantity small or great, those materials to some extent will be taken in solution. The second law is the fundamental principle of chemical dynamics, viz., Chemical action is proportional to the active mass. To illustrate, other things being equal, the greater the quantity of a compound present the greater the quantity which will be taken into solution and deposited from solution.

The materials will be likely to be taken into solution in large measure during the descending course of the water, and deposited from solution in large measure during the ascending course of the water. For this there are a number of reasons. First, solution is likely to occur during descension because the conditions are those of increasing temperature and pressure. It is well known that increase of temperature greatly increases the solvent power of water. In many cases a slight rise in temperature is sufficient to increase this activity in an amazing degree; in fact, out of all proportion to the increase of temperature. Deposition is likely to occur during ascension because the conditions are those of decreasing temperature and pressure.* Second, some substances are held in solution better than others Certain substances, such as quartz, may be deposited during the downward course of the water, and a more soluble substance, such as gold, silver, or some other substance, be dissolved at the same time. Third, the larger openings, such as fissures, are the trunk channels of water circulation. In them the waters from different sources mingle; and this, to my mind, is the most important single factor—probably the dominant factor—in the precipitation of ores. If the contents of half a dozen test tubes filled with solutions chosen at random be dumped together, a precipitate is almost sure to form. And just so sure as underground waters come from this source and that source and mingle in the trunk channels of underground circulation, just so surely are precipitates formed. Fourth, in the formation of an ore deposit the wall rock may contribute a solution which precipitates a metal, or it may contribute a metal which is precipitated by a solution. Consequently an ore deposit may be confined to a particular horizon where there is a certain rock. For instance, lead and zinc are very generally associated with limestone, and the sandstones and other rocks above or below are very likely to be deficient

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* The relations of temperature and pressure to solution and precipitation are much more complicated than applied in the above general statement. For a more nearly exact expression of the facts, see Some principles controlling the deposition of ores, by C. R. Van Hise: Separate from Trans. Am. Inst. Min. Engineers, vol. XXX, 1900, pp. 38–43.

or nearly devoid of these metals. To a less extent other ores show a decided preferences for limestone as compared with other rocks. The explanation may be that the limestone itself furnishes the material; and this is believed to be the fact in various cases. The explanation may be that the limestone furnishes a precipitating agent to solutions derived from other rocks. It may be that the limestone, because of its ready solubility furnishes large openings in which big deposits may be formed. Finally, the explanation may lie in the combination of two or more of these factors. I have no doubt if we consider the whole world each of these factors is important, and that in some cases all of them co-operate.

As a result of the combination of the various factors above considered, a porous rock, or an opening, once in a million or ten million times receives enough of the metallic materials in solution so that a fraction of an ounce of gold per ton, or a few ounces of silver per ton, or a few per cent. of copper or some other metal, or a large per cent. of iron, will be precipitated; and we call the material an ore deposit. An ore deposit it is from an economic point of view. From a geological point of view it is usually to a far greater extent quartz and calcite and other gangue minerals.

I wish now to go a little further and consider the fissure on the slope shown in this chart (Fig. 6), both in the past and the present. At some distant time in the past suppose the surface and level of groundwater, instead of being as shown, were at much higher levels, have since been greatly lowered by the processes of denudation. Where would the upper part of the fissure shown, the water of which is descending, be with reference to the circulation at that time? It would be where the lower part of the fissure now is, would it not? It would be where the waters are ascending, as shown in the lower part of the fissure. Therefore, for the part of the fissure where the water is now descending it may be that the first contribution of ore was made by ascending waters, although descending waters are now the only important factor. But as denudation went on the condition would gradually change. The part of the fissure under consideration would pass through a stage in which the waters would mainly come in laterally. As denudation went still farther the waters might all be descending, and in the extension of the fissure below the waters might come in laterally, and still deeper might be ascending. We must now still further amplify our theory, must we not? To explain the entire ore deposit we have to consider all parts of the ore deposit throughout its entire history. At present ore deposition by descension, by lateral secretion, by ascension, is somewhere occurring in the fissure; but not only is this the case, but all have

worked in turn in the upper part of the deposit. Therefore, this further complicates the theory of ore deposition.

Now I wish to give some facts as to the actual occurrences of ore deposits before I go to the next step in theory. At Butte, Mont., are famous copper deposits. In the copper lodes of this district, in the very upper part of the deposits, above the level of groundwater, there were oxidized ores which carried high values in silver and gold, but very low values in copper. At and a short distance below the level of groundwater there were very high values in copper as sulphides. "There follows below a region of varying height, of valuable rock, which again slowly deteriorates in depth; this deterioration, however, being so retarded finally as to be scarcely appreciable."* This deep ore is mainly copper-bearing pyrites. Douglass tells us that in depth every copper deposit of the entire Appalachian region of the United States shows only cupriferous pyrrhotite. An excellent illustration is Ducktown, Tenn., where at the level of groundwater was a very rich deposit of chalcocite but a few feet thickness which rapidly changed into very low grade cupriferous pyrrhotite.† In Australia down to the level of groundwater are high values in native gold; below the level of groundwater are auriferous pyrites bearing relatively small values of the precious metals.‡ Some of the superintendents say where ounces of gold are found above the level of groundwater only pennyweights are found below.§ In the Sierra Nevada of the United States, according to Lindgren,|| above the level of groundwater the gold values ran from $80 up to $300 per ton; but below the level of groundwater, where there are sulphurets, the values average from $20 to $30 per ton. Notwithstanding the fact that occurrences such as those mentioned are typical of the ore deposits of many districts of the world, it has been believed by many practical mining men that ore deposits become richer upon the average with increase of depth; but it must be ad-

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*The ore deposits of Butte City, by R. C. Brown: Trans. Am. Inst. Min. Eng. vol. XXIV, 1895, p. 556.

†The persistence of lodes in depth, by W. P. Blake: Eng. and Min. Jour., vol. LV, 1893, p. 3.

†The Ducktown ore deposits and the treatment of the Ducktown copper ore, by C. Henrich: Trans. Am. Inst. Min. Eng., vol. XXV, 1896, pp. 206–209

‡The alterations of the Western Australian ore deposits, by H. C. Hoover: Trans. Am. Inst. Min, Eng., vol. XXVIII, 1899, pp. 762–764.

§The genesis of certain auriferous lodes, by J. R. Don; Trans. Am. Inst. Min. Eng., vol. XXVII, 1898, p. 596.

||The gold-quartz vein of Nevada City and Grass Valley, Cal., by Waldemar Lindgren: Seventeenth Am. Rept. U. S. Geol. Surv., 1895-1896. Pt. II, p. 128, L 896.

mitted that the facts do not justify this sanguine expectation. In fact nine mines out of ten, taking the world as a whole, are poorer the second 300 meters than they are the first 300 meters, and are poorer the third 300 meters than they are the second 300 meters. In fact many ore deposits have been exhausted or have become so lean as not to warrant working before the 300 meter level is reached; while comparatively few ore deposits have been found to be so rich as to warrant working at depths greater than 1,000 meters.

There are, however, some ore deposits which are not known to decrease in richness with depth so far as yet exploited. There are a considerable number of deposits which, after a first rapid decrease in richness, maintain their tenor pretty well to the depth of 300, 500, or even 1,000 meters, and some few deposits maintain their richness at even greater depths. But we cannot reasonably hope that a deposit will get richer with depth provided we use a 300 meter unit for measurement. The most sanguine view which is ever justified for any deposit is that, using a 300 meter unit, that the second shall be as good as the first, and the third as good as the second. While the above is true there are very great irregularities in the richness of ore deposits, both favorable and unfavorable, due to multifarious causes, which I cannot possibly discuss to-night, but which I considered somewhat fully in the Institute paper.* These irregularities are especially marked in the upper 300 meters of a deposit; so that in many cases if the unit of measurement were 10 meters or 30 meters, or in a few cases 100 meters even, it might be said that the deposits are becoming richer with depth, although the reverse also occurs in many cases. The truth is that in the uppermost part of an ore deposit the variations in richness with depth are extreme, and no definite rules can be laid down in reference to them.

Now, what is the explanation of these irregularities and of the very general diminution of richness with depth? What is the explanation in some cases of the relatively even values at variable depth? The last question will be first considered.

In those instances in which the tenor is maintained or practically maintained from the surface to a great depth the ore is believed to be the result of a single concentration by ascending waters. Such ore deposits may continue without any appreciable diminution in richness to the lowest limits to which man may expect to penetrate the earth; but these are exceptional cases. Even ore deposits which are the result of a single concentration by ascending water

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*Some principles controlling the deposition of ores, by C. R. Van Hise: Trans. Am. Inst. Min. Eng., vol. XXX, 1900, pp. 102–112.

may diminish in richness at considerable depth. It has been seen that in the fissure at the bottom of the valley on this chart (Fig. 6) that the water ascends to the surface. It is evident that the upper part of the fissure receives the greatest supply of water, and this water to a large extent does not penetrate any great depth; while the lower part of the fissure receives less water, but this water penetrates to a considerable depth. It may happen that the water relatively near the surface traverses the rocks containing the main supply of metals, and therefore brings the chief contributions of valuable material, or such waters may carry the precipitating agent. In such instances the ore deposits produced by ascending water alone, would diminish in richness with depth; but such decrease would not be likely to be very rapid. Upon the other hand, if the above conditions be reversed, a deposit may increase in richness for a considerable depth, but as a matter of fact this appears to be a very infrequent case.

As illustrations of the ore deposits of the class produced by ascending waters alone, are the copper deposits of Lake Superior. These deposits, while very bunchy and extremely irregular in the distribution of copper, are wonderfully persistent in depth. The copper of the ore was deposited in the metallic form. As compared with sulphides, this material is not readily oxidized. In this district the rocks above the level of ground water are not appreciably weathered. Doubtless there was a belt of weathered material before the glacial epochs, but if so, it has been swept away by ice erosion, and since the glacial period sufficient time has not elapsed to weather appreciably the rocks which now lie within the theoretical belt of weathering. If there once were in this district an upper belt of weathering in which there were deposits of exceptional richness this material has been removed. However, in this district a first concentration by ascending waters was adequate, but it is not often that a first concentration produces deposits of such richness as those adjacent to Calumet and Houghton on Keweenaw Point; and, indeed, this is exceptional even in the Keweenawan of the Lake Superior region; for while concentrations of copper have occurred at many points in the rocks of this period, as yet at no other locality have those concentrations been found to be so abundant and rich as to warrant exploitation on a large scale.

I now turn to the question as to the cause of frequent diminution of richness of ore deposits with depth. Many or most of such ore deposits are believed to be the products of two concentrations, the first by ascending, the second by descending waters. In this connection it is necessary to call attention to the fact that a large

proportion of the ore deposits which are being exploited are below some part of the slope. It may be said that the reason for this is that the low grounds are more difficult to explore and work; but giving due allowance for this, it still seems to me that the majority, perhaps the great majority, of very rich deposits are below slopes and crests and not below the valleys. I believe the richer deposits are below the slopes because at these places a second concentration is possible and probable.

Returning now to this chart (Fig. 6) we shall direct our attention to the fissure on the slope. This fissure once extended up through the overlying rocks which have been removed by denudation. What has become of the ore in the part of the fissure which has been worn away? If for instance it carried 5 per cent copper, what has become of it? A part of it would have been scattered far and wide through erosive action; but a part of it would have been taken into solution and redeposited in the same vein deeper down. In the belt of weathering oxidized salts, such as sulphates, would form; the descending waters would carry these products downward; and it is my belief that they would react upon the solid lean sulphides below with the result of precipitating the metals from the descending solutions. Now this has been held to be a mere unverified assumption by some geologists; but it seems to me that they have not fully considered the certain effects of the chemical laws concerned. We know if in a laboratory a solution of copper sulphate or other copper salt be placed in contact with iron sulphide that copper will be thrown down as copper sulphide. If the copper solution be placed in contact with a lean copper-iron sulphide a sulphide richer in copper will be produced. And if these reactions occur in the chemical laboratory, will they not as certainly occur in the laboratory of nature, although perhaps more slowly?

At this point it is to be recalled that in many copper deposits above the level of groundwater oxides and carbonate occur; while below the level of groundwater are sulphides. Moreover at high levels these sulphides are rich in copper; and they usually become poorer in copper sulphide and richer in iron sulphide at the lower levels. You will remember at Butte, Mont., at and for a distance below the level of groundwater, are rich copper sulphurets, which grade at depth into leaner copper sulphides containing correspondingly large amounts of iron sulphide. You will remember the same is true for the entire Appalachian region. You will remember that frequently above the level of groundwater gold lodes are exceedingly rich. What is the explanation of these and similar curious facts? What is the explanation of the exceptional or

even extraordinary richness of the deposits at and near the level of groundwater, and of the low grade cupriferous pyrites deep below the level of groundwater? In my opinion the only plausible explanation is that the rich parts of the deposits have received two concentrations, the first by ascending waters and the second by descending waters. The metals of the rich portions of the deposits were largely contributed by the parts of the deposit above or once above the rich parts. In some cases portions of the depleted veins remain, as at Butte; but frequently the depleted parts of the veins have been removed by erosion. The remote source of the material was therefore the metals deposited by the first concentration. But let us follow the matter still further. In the majority of cases the denudation continued, the parts of the ore deposits produced by the second concentration rise into the belt of weathering. They may there be partly or wholly transformed into rich oxidized products, or they may be depleted to extend the rich deposits below.

In the concentration by descending waters the chief chemical reactions are bound to be between the oxides or salts of copper and the sulphide of iron. The precipitation of copper sulphide resulting may occur in various ways.

The reaction may produce chalcopyrite, as shown by the following equations:

$$CuSO_4 + 2FeS = CuFeS_2 + FeSo_4 \quad \text{or}$$
$$CuSO_4 + 2FeS_2 + O_4 = CuFeS_2 + FeSO_4 + 2SO_2.$$

The reactions may produce bornite, as shown by the following equations:

$$Cu_2SO_4 + CuSO_4 + 3FeS = Cu_3FeS_3 + 2FeSO_4 \quad \text{or}$$
$$Cu_2SO_4 + CuSO_4 + 3FeS_2 + 6o = Cu_3FeS_3O + 2FeSO_4 + 3SO_2.$$

Or the reactions may directly produce chalcocite, as shown by the following equations:

$$Cu_2SO_4 + Fe\,S = Cu_2S + FeSO_4 \quad \text{or}$$
$$Cu_2SO_4 + FeS_2 + O_2 = Cu_2S + FeSO_4 + SO_2.$$

If the reactions are between a copper salt and sulphide bearing copper various reactions throwing down the copper may also occur. The reactions may be upon chalcopyrite, producing bornite, as shown by the following equation:

$$2CuFeS_2 + CuSO_4 + O_2 = Cu_3FeS_3 + FeSO_4 + SO_2.$$

It may be the reaction of copper sulphate upon chalcopyrite or bornite, producing chalcocite, as shown by the following equations:

$$CuFeS_2 + CuSO_4 + O_2 = Cu_2S + FeSO_4 + SO_2 \quad \text{or}$$
$$Cu_3FeS_3 + CuSO_4 + O_2 = 2Cu_2S + FeSO_4 + SO_2.$$

It may be by the reaction of copper oxide or copper sulphate upon covellite, producing chalcocite, as shown by the following equations:

$$6CuS + 2Cu_2O = 5Cu_2S + SO_2 \quad \text{and}$$
$$6CuS + 2Cu_2SO_4 + 3H_2O = 5Cu_2S + 2H_2SO_4 + H_2SO_3.$$

Parallel sets of reactions could be, and, indeed, are, written in my full paper upon the subject of ore deposits, which explain the formation of the rich sulphides of lead, zinc and silver through the reactions of the oxidized products of these metals upon sulphide of iron, producing rich sulphides of lead, zinc and silver. However, time does not suffice to present these this evening. The particular reaction in an individual case will depend upon the relative solubilities of the various compounds present, upon the law of mass action, upon the pressure and temperature, and upon various other factors.

Now, I do not assert of the equations which have been written for copper and other metals that the reactions represented occur exactly as written, but I do assert that reactions of the general character represented occur, by which the oxidized products of the metals in solution are thrown down by the lean sulphurets, producing rich sulphurets. I have no doubt that many other reactions besides those written take place. It is exceedingly difficult to ascertain the particular reactions which occur at a given time and place; but I think it is perfectly clear that reactions occur of the type of those written. I cannot attempt to give you all the evidence on the point, but to me the case is demonstrative. If this be correct, we now have an explanation of the fact that a great many ore deposits are rich at high levels and become poorer with depth. These ore deposits have undergone two concentrations, a first concentration deposited by ascending waters and a second concentration deposited by descending waters. The supplies for the first concentration were obtained from the widely dispersed and small amounts of material disseminated through the rocks. The supplies for the second concentration were derived from an earlier concentration.

In the foregoing statements the second concentration of metals by solution, downward transportation, and precipitation by reactions upon the sulphides of an earlier concentration, has been emphasized. However, it is not supposed that this is the only process which may result in enrichment of the upper parts of ore deposits by descending waters. The enrichment of this belt may be partly caused (1) by reactions between the downward moving waters carrying metallic compounds and the rocks with which they

come in contact, and (2) by reactions due to the meeting and mingling of the waters from above and the waters from below:

(1) The metallic compounds dissolved in the upper part of the veins carried by descending waters may be precipitated by material contained in the rocks below. This material may be organic matter, ferrous substancees, etc. So far as precipitating materials are reducing agents, they are likely to change the sulphates to sulphides, and precipitate the metals in that form. While sulphides may thus be precipitated either above or below the level of ground water, they are more likely to be thrown down below the level of ground water. Other compounds than reducing agents or sulphites may precipitate the downward moving salts in other forms than sulphides.

(2) In a trunk-channel, where waters ascending from below meet waters descending from above, there will probably be a considerable belt in which the circulation is slow and irregular, the main current now moving slowly upward and now moving slowly downward, and at all times being disturbed by convectional movements. Doubtless this belt of slow general movement and convectional circulation would reach a lower level at times and places of abundant rainfall that at other times and places, for under such circumstances the descending currents would be strong. The ascending currents, being controlled by the meteoric waters falling over wider areas, and subject to longer journeys than the descending currents, would not so quickly feel the effect of abundant rainfall. Later, the ascending currents might feel the effect of the abundant rainfall and carry the belt of upward movement to a higher level than normal. However, where the circulation is a very deep one, little variations in ascending currents result from irregularities of rainfall.

In the belt of meeting ascending and descending waters (see Fig. 6) convectional mixing of the solutions due to difference in temperature would be an important phenomenon. The waters from above are cool and dense, while those from below are warm and less dense. In the neutral zone of circulation, the waters from above would thus tend to sink downward, while waters from below would tend to rise, and thus the waters would be mingled. Still further, even if the water was supposed to be stagnant at the neutral belt, it is probable that by diffusion the materials contributed by the descending waters would be mingled with the materials contributed by the ascending waters.

Ascending and descending solutions are sure to have widely different compositions, and precipitation of metalliferous ores is a certain result. As a specific case in which precipitation is likely to occur, we may recall that waters ascending from below contain practically no free oxygen, and are often somewhat alkaline, while waters descending from above are usually rich in oxygen and

frequently contain acids, as at Sulphur Bank, described by Le Conte.* The mingling of such waters as these is almost sure to result in precipitation of some kind. Le Conte further suggests† by the mingling of the waters from below with those from above that the temperature of the ascending column will be rapidly lessened, and this also may result in precipitation, but the dilution would work in the reverse direction.

The metals precipitated by the mingling of the waters may be contributed by the descending waters, by the ascending waters, or partly by each. In so far as more than an average amount of metallic material is precipitated from the descending waters, this would result in the relatively greater richness of the upper part of veins independently of the material carried down from above.

In all the cases considered, the precipitation and enrichment of the upper parts of deposits follow from the reactions of downward moving waters. Their effect may be to precipitate the metals of the moving ascending water to some extent, and thus assist in the first concentration. But the results of these processes cannot be discriminated from the concentration resulting from an actual downward transportation of the material of an earlier concentration. In concluding this part of the report, *it is held that the downward transportation of metals already in lodes is the most important of the causes explaining the character of the upper portions of ore deposits; and that their peculiar characters are certainly due to the effect of descending waters.*

The concentrations by ascending and descending waters have been considered as if they were mainly successive. In some instances this may be the case; but it is much more probable that ascending and descending waters are ordinarily at work upon the same fissure at the same time, and that their products are, to a certain extent, simultaneously deposited. For instance, under the conditions represented by this chart (Fig. 6) a first concentration by ascending waters is taking place in the lower part of fissure, and a reconcentration by descending waters is taking place in the upper part of the fissure. Between the two there is a belt in which both ascending and descending waters are at work. The rich upper part of an ore deposit which is worked in an individual case may now be in the place where ascending waters alone were first acting, where later, as a consequence of denudation, both ascending and descending waters were at work, and still later, where descending waters alone were at work. The more accurate statement concerning ore depos-

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* On the genesis of metalliferous veins, by Joseph Le Conte: Am. Journ. Sci., third ser., vol. XXVI., 1883, p. 9.

† Le Conte. op. cit., p. 12.

its, produced by ascending and descending waters, is therefore that ascending waters are likely to be the potent factor in the closing stage of the process.

Also, for the sake of simplicity in the consideration of the concentrations I have disregarded the lateral elements of the moving water. In many cases superimposed upon the vertical movements in the fissures or other openings are lateral movements, as a result of which the deposits instead of being in vertical positions are inclined, often much inclined, and, indeed, may be horizontal or even locally descending. Moreover, the horizontal extents of the deposits may be much greater than the vertical extents. Reduced to a simple and broad statement, *The first concentration of many ore deposits is the work of a relatively deep water circulation, while the reconcentration is the result of reactions upon an earlier concentration through the agency of a relatively shallow water circulation. Commonly the deep water circulation is lacking in free oxygen and contains reducing agents, and the shallow water contains free oxygen. The deep water is therefore a reducing and the shallow water an oxidizing agent.*

In addition to the general factors already considered there are many special factors which have a most important, indeed, very often a controlling, influence in the production of ore-chutes and in the localization of ore in certain areas and districts. Some of these factors are the complexity of openings, the presence of impervious strata at various depths, the presence of pitching folds, the character of the topography. I see, however, that my time is nearly gone and I shall not take up their discussion this evening, but must refer those especially interested in this phase of the subject to my full paper already repeatedly mentioned.* I must however note that impervious strata are frequently of controlling importance in the underground circulation. Often deep and shallow water circulations are separated by such strata. Often, also, as the result of the removal of impervious strata by denudation, the previous deep circulation ceases and the action of the shallow circulation is inaugurated.

At this point it may be well to briefly recall the most fundamental features of the water circulation which produces the ore deposits. First comes the action of the downward-moving, lateral-moving, waters of meteoric origin which take into solution metalliferous material. These waters at depth are converged into trunk channels, and there, while ascending, the first concentration of ore deposits may result. After this first concentration many of the ore deposits which are worked by man have undergone a later concentration not

* Some principles controlling the depositions of ores, by C. R. Van Hise: Trans. Am. Inst. Min. Eng., vol. XXX, 1900, pp. 112–146.

less important than the earlier as a result of shallow descending, lateral-moving waters. In other cases a concentration by descending, or lateral-moving waters alone is sufficient to explain some ore deposits. It thus appears more clearly than heretofore that an adequate view of ore deposits must not be a descending water theory, a lateral-secreting water theory, or an ascending water theory alone. While an individual ore deposit may be produced by one of these processes, *for many ore deposits a satisfactory theory must be a descending, lateral-secreting, ascending, descending, lateral-secreting theory.*

But there is no question in my mind that this theory is still insufficient to fully explain many of the ore deposits. No knowledge is ever complete. We move step by step, carrying a theory nearer and nearer to completion. If, however, a theory be based on good work, it usually will not prove to be false; it will be found to be incomplete. Sandberger was not wrong when he said lateral secretion explained many things in reference to ore deposits. He was wrong only when he excluded other factors. He became unscientific when he carried his theory further than his observations justified. While the theory here proposed is believed to make an important advance, it will sooner or later be found to be incomplete. I trust it will not be found to be false. But the most that I can hope for it is that it is approximately correct as far as it goes.

It is believed that the principles which have been presented lead to a new and natural classification of the ore deposits produced by underground water. As already noted, ore deposits may be divided into three groups: (1) ores of igneous origin, (2) ores which are the direct result of the processes of sedimentation, and (3) ores which are deposited by underground water.

Since the ores produced by igneous agencies and those produced by processes of sedimentation have not been considered in this paper, a subdivision of these groups will not be attempted.

Ores resulting from the work of ground water, group (3) above, may be divided into three main classes:

(a) Ores which at the point of precipitation are deposited by ascending waters alone. These ores are usually metallic or some form of sulphuret; but they may be tellurides, silicates or carbonates.

(b) Ores which at the place of precipitation are deposited by descending waters alone. These ores are ordinarily oxides, carbonates, chlorides, etc., but silicates and metals are exceptionally included.

(c) Ores which receive a first concentration by ascending waters and a reconcentration by descending waters. The concentration by ascending waters may wholly precede the concentration by de-

scending waters, but often the two processes are at least partly contemporaneous. The materials of class (c) comprise oxides, carbonates, chlorides, and rarely metals and silicates above the level of ground water, and rich and poor sulphurets, tellurides, metalic ores, etc., below the level of ground water. At or near the level of ground water these two kinds of products are more or less intermingled, and there is frequently a transition belt of considerable breadth.

How extensive are the deposits of class (a) I shall not attempt to state. Indeed, I have not such familiarity with ore deposits as to entitle me to an opinion upon this point. However, a considerable number of important ore deposits belong to this class. This class is illustrated by the Lake Superior copper deposits.

The ore deposits of class (b) are important. Of the various ores here belonging probably the iron ores are of the most consequence. A conspicuous example of deposits of this kind are the iron ores of the Lake Superior region.

It is believed that the ore deposits of class (c) are by far the most numerous. I suspect that a close study of ore deposits in reference to their origin will result in the conclusion that the great majority of ores formed by underground water are not the deposits of ascending waters alone, but have by this process undergone an early concentration, and that descending waters have produced a reconcentration, as a result of which there is placed in the upper 50 to 500, or possibly even 1,000 meters of an ore deposit, a large portion of the metalliferous material which originally had, as result of the early concentration, a much wider vertical distribution.

To the foregoing classification objections will at once be made: It will be said that there are no sharp dividing lines between the groups and classes. To this objection there is instant agreement. Transitions are everywhere the law of nature. It is well known that there are gradations between different classes of rocks, * and this statement applies equally well to ore deposits. I even hold that there is gradation between ore deposits which may be explained wholly by igneous agencies and those which may be explained wholly by the work of underground water or by processes of sedimentation.

I have elsewhere held that there is complete gradation between waters containing rock in solution and rock containing water in solution.† If there be no sharp separation between water solutions and magma it is probable that this is also true in reference

*The naming of rocks. By C. R. Van Hise: Journ. of Geol., Vol. VII, 1899, pp. 687-688.

†Principles of North American pre-Cambrian geology, by C. R. Van Hise: Sixteenth Ann. Rept. U. S. Geol. Surv., 1894-95, Pt. I, p. 687.

to ore deposits of direct igneous origin and those produced by underground water. There may be ore deposits in which water action and magmatic differentiation have been so closely associated that one cannot say whether the resultant ore deposit is mainly a water deposit or mainly a magmatic deposit. But for the vast majority of ore deposits, if I properly apprehend the relations, the broad general statements which I have made apply. Ordinarily there is little difficulty in discriminating between veins and dikes, the first representing crystalizations from water solutions, the second crystalizations from magma. There are few cases where the discrimination in reference to ore deposits is not easy. While gradation between water deposited ores and igneous ores are uncommon, gradations between the different classes of ore deposits formed by underground water are common.

Ores which have received a first concentration by igneous agencies or by processes of sedimentation are sure to be reacted upon by the circulating underground waters, and thus a second or even a third concentration may take place. The first concentration by igneous or sedimentary processes may be the more important or dominant process. In some cases, therefore, the ores may be referred to as produced by igneous agencies, in others as produced by these in conjunction with underground waters, and in still others as produced mainly by underground waters.

Ore deposits which are precipitated almost solely by ascending waters will grade into those in which descending waters have produced an important effect, and thus there will be transition between classes (a) and (c). Similarly there will be every gradation between classes (a) and (b) and between classes (b) and (c). If this be so it will not infrequently happen that a single fissure may fall partly in one class and partly in another. Thus a single ore deposit may belong partly in class (a) and partly in class (c). However, in most cases the workable part of a deposit will largely belong to one of the three classes. Not only are there gradations between different varieties of the ore deposits, but there are gradations between the ore deposits and the rocks ; for the ore deposits in many cases are not sharply separated from the country rocks, but grade into them in various ways.

In answer to the above objection concerning gradations, it may be said that I know of no classification of ore deposits which has yet been proposed to which the same objection may not be urged with equal or greater force.

However this retort does not give any criterion by which the usefulness of the above classification may be tested. The test is, does this classification give a more satisfactory method of studying ore deposits than has heretofore been possible? Will an attempt

to apply this classification assist mining engineers and geologists in accurately describing ore deposits? Will the classification to a greater extent than any previous one give engineers rules to guide them in their expenditure in exploration and exploitation? By these criteria I am willing that the classification shall be tested.

As an illustration of the practical usefulness of the classification is the connection between genesis and depth. The character of a deposit in most cases will determine to which class it belongs. Where the ores are deposited by ascending waters alone it has been pointed out that this is favorable to their continuity to great depth. Therefore, where a given ore deposit has been shown to belong to this class, the expenditure of money for deep exploration may be warranted; although as already pointed out such deposits may decrease in richness with depth. Where a deposit is produced by descending waters alone, the probable extent in depth is much more limited. In such cases, when the bottom of the rich product is reached, it would be the height of folly to expend money in deep exploration. Where the ore deposit belongs to the third class, that product by ascending and descending waters combined, there will again be a richer upper belt composed of rich oxidized and sulphureted deposits which we cannot hope will be duplicated at depth. To illustrate, it would be very foolish at Ducktown, Tennessee, to sink a drill hole or shaft into the lean cupriferous pyrrhotite with the hope of finding rich sulphurets, such as those which were mined near the level of groundwater. Those who have spent money in deep prospecting of the lean pyrrhotite in the Appalachian range will doubtless agree to this statement. Deposits produced by two concentrations may grade into the class produced by ascending waters alone and after the transition the deposits may be rich enough to warrant exploitation at depth; but if such work be undertaken it must be done with the understanding that the rich upper products will not be duplicated at depth. It therefore appears to me that the determination to which of the classes of ore deposits produced by underground waters a given ore deposit belongs has a direct and very important practical bearing upon its exploration and exploitation.

DISCUSSION.

Mr. J. P. Iddings—I am, of course, very much interested in the paper by Prof. Van Hise, but have not worked along the direction of circulating waters or mineral deposits. However, in his discussion of the zone, or the depth, to which cracks or openings may exist, it seems to me, as I have heard him from time to time, that he leaves out of account a factor which undoubtedly

exists. As I recollect Prof. Schlicter's discussion of the possibility of an opening filled with liquid (water) below the crust of the earth, it was a simple question in dynamics, in which the crushing strength of the material was offset against the pressure exerted within the rock toward the cavity, and from the cavity or the liquid toward the rock, and of course when the difference between the pressure toward the cavity and the pressure from the cavity back is greater than the crushing strength of the rock it yields, and as I recollect it the depth was derived from the consideration of the weight of a column of water. Now, when the water has a different gravity it will have a greater weight, and, therefore, there will be a greater depth at which the cavity can exist. As waters descend, we understand that they are more capable of taking things into solution. As they take things more into solution they naturally become heavier. We also are led to believe that waters at high temperature under considerable pressure may take a large amount of the materials in the crust of the earth in solution. In fact, we find no limit to the solubility of minerals in water under high temperature and pressure. In other words, there is no limit between waters containing the silicate minerals of rocks in small amounts, and those with large amounts, until we get a liquid which consists of these minerals in the liquid form with a varied amount of water, that is to say, an igneous mass. We are now approaching the question of volcanic lavas. When there is pressure there is a possible transition from an aqueous solution of silicates to a solution consisting of silicates with a small amount of water. Of course, when we have such a solution we have a very heavy liquid, and the difference then between the pressure of the liquid against the rock, and the pressure of the rock against the liquid, is much smaller. As this liquid approaches in density the rock, of course, it is quite evident that the possibility of the rigid rock being parted and filled with liquid of nearly its own density is such that what we call a crack—that is to say parting of a rigid body—may exist when it is filled with a liquid of great density to a very great depth, and a very much greater depth, of course, than 10,000 meters. So that it would seem that, while in the present discussion there was mainly the question of surface water with a small amount of material in solution, at a greater depth with greater heat and with more in solution, the limit to which these waters may circulate is probably deeper than that mentioned by Prof. Van Hise; and such expressions as "the impossibility of fissure or cracks not being possible below 10,000 meters," when we mean by them not fissures and cracks occupied by space or gas only, but occupied by liquid, needs qualification.

Professor T. C. Chamberlin—I am so thoroughly in accord with the

speaker of the evening that it seems superfluous for me to discuss the subject. I find practically nothing from which to dissent, and everything to commend. It seems to me that this line of approach is emphatically the true one. The fundamental proposition advanced by Professor Van Hise, that all appreciable fissures and cavities close at comparatively shallow depths, using earth-measures, is, beyond any question, sound; so, also, is the proposition that the circulation is more ample in the upper reaches than in the lower ones. It seems to me, also, that the generalization—perhaps not expressed in so many words in the address—that the chemical activity in the upper horizons is more effective than in the lower horizons, notwithstanding the aid of temperature and pressure below, is also well taken, because it is in the upper horizon that there is a contact between two great chemical spheres, the atmosphere and the solid earth, with water, the great intermediary, playing a part on both sides. This is the greatest of all contact zones, and at and near it the greatest chemical reactions take place, among which are those upon which concentrations are most largely, but not by any means wholly, dependent. Therefore, instead of looking to the deep interior for the main source of ores, we are to look to this zone of highest chemical activity, and, next to it, to the remaining portion of the fracture zone through which the meteoric waters circulate, which is relatively superficial, but extends deep enough to bring into play elevated temperatures and high pressures. This is essentially the conclusion of the speaker of the evening—liberally construed—who locates the greater ore values in the vicinity of the surface of the underground water which is the most effective horizon of the contact zone. This is, perhaps, not what we would desire, but what we desire in this matter is of no commercial consequence. That only is serviceable in practical business, which is true; and if this is true, it is, as Professor Van Hise has urged, extremely important that we should know it, and should guide ourselves by it. The popular dictum, that ores increase as they go down, probably arises from the great preponderance of very superficial work. Ores do, as a rule, increase in richness down to the water level, and often for some distance below. At the *immediate* surface of the earth, leaching predominates, and the descending waters carry the dissolved ores to points below. The actual surface of the earth is, therefore, lean, and in prospecting, and in the early stages of mining, this leaner portion is first encountered. As work descends, portions less and less leached are reached, and at length the zone of secondary concentration, which may have its most productive portion at some scores or hundreds of feet below the surface. Down to this point the popular generalization holds true. But in the larger measure which Professor

Van Hise has used—and explicitly so stated—the opposite proposition holds true, with some notable exceptions. This is one of those frequent cases in which a popular generalization is true within the superficial range of popular investigation, but fails when projected beyond that.

The commingling of waters was named among the essential factors, but not much elaborated for lack of time. This seems to me, however, to best express the gist of the whole subject. If I were to take issue with Professor Van Hise's views in any respect at all, it would be just here. I would place more emphasis on the conditions that brought about the commingling of waters of different kinds without regard to whether they were ascending or descending, as such. Waters that have pursued different courses and have become differently impregnated because of their different courses, coming together in the course of their circulation, chiefly in the main fissures which form the trunk lines of circulation, react upon each other, and deposition is an almost inevitable consequence. While the different courses may be, the one ascending and the other descending, they may, also, both be descending or, perhaps, both be ascending, and these cases, I think, are not unimportant. For instance, in the lead and zinc deposits of the Upper Mississippi valley, some of the descending waters may percolate slowly through the metalliferous limestones and become mineralized and finally work their way out into the main fissures, while the other waters may go directly down into the main fissures and there mingle with the mineralized waters and cause deposition. But this is a question of emphasis rather than of disagreement, and Professor Van Hise would take no serious objection, I think, to the point I make. It seems to me that the method of Professor Van Hise is one of the most important which has yet been brought to bear upon this important subject. I feel sure that it marks a new epoch in the philosophy of ore deposits and in their economical exploitation.

Mr. O. C. Farrington—I came as a learner, not as an oracle, but I want to thank Prof. Van Hise for the new views which he has given me on this question, and especially speak with approval of the impregnable position which it seems to me he has taken regarding the impossibility of fissures occurring at great depth. Some of us possibly know how difficult it is to keep the walls of a vein apart after the ores have been removed, and therefore can understand how true Prof. Van Hise's conclusions are in this regard. There is only one point that I thought needed, perhaps, a little qualifying; that is, it did not seem to me that quite enough consideration was paid to the effect of temperature in increasing the solvent power of water. Any one who has worked in a laboratory knows to what a great extent a little increase of temperature increases the solvent power

of a liquid. So it seems to me it might not be correct altogether to speak, as Prof. Van Hise has done, of the upper zone as one of solution and the lower zone as one of deposition, because as the waters go down and become heated their power of solution will be increased, and as they rise again and the temperature is reduced it seems to me that then and there we should have deposition. I wish that Prof. Van Hise had had time to give us a little more of the practical outcome of his classifications, so that we might know how to distinguish ores deposited by ascending and descending waters. As a museum man I would like to adopt a classification which would separate the ores in such a way. But so far as his paper has told us, I judge there would be no way of making such distinctions outside of visiting the ground itself. And further, so far as the practical outcome goes, if I understand him correctly, we may conclude in each case that the ores do not increase in richness in depth, and that there would be no variation in this regard in the two kinds of deposits. Am I correct, Professor Van Hise?

Prof. Van Hise—Yes; except for the qualification which I make in my fuller statement.

Mr. L. L. Summers—Professor Van Hise has confined his discourse largely to the occurrence of ores of the baser metals, such as copper, iron, lead, etc., but inadvertently has made rather a sweeping statement that the value of an ore deposit would not increase with depth. This statement, I take it, is based upon the assumption that the ore has been deposited by water of meteoric origin, and referring to the map before you he shows that this water falling on high ground descended through porous soil or fissures and was forced upward by the difference in hydraulic head. In other words, from purely an engineering standpoint it is simply a question of the area of precipitation that higher than the area of ore deposit.

In the case of the precious metals, particularly gold, some of the richest mines are located at elevations of 10,000 to 11,000 feet above sea level. The drainage area above them is of such limited extent that they could hardly have derived the ore depositing solutions from this source. I am aware that attention has been called to the effects of erosion, and that in many localities the present elevations were not those that existed when the ore deposits may have occurred, but in the Cripple Creek district, for instance, the ore bearing district is essentially of volcanic origin and of comparatively recent date. From the spreading of the veins near the surface, while they are concentrated lower down, it is known that when the waters circulated the surface was not greatly different from that now existing, and erosion therefore has not been extensive since the solutions deposited the ore; hence, erosion could hardly have

changed the contour of the country materially since the ore-bearing solutions circulated. The flow off of ordinary soil, such as that in the western states, varies from 10 to 60 per cent, but in the rock countries it is often 90 to 95 per cent, so that a very limited amount would seep through the soil and cause the hydraulic head necessary to circulate the water at the elevations now existing. There is ample reason for believing the solutions which deposited the ore in this particular region were hot solutions—and incidentally Professor Van Hise seems not to have awarded temperature and pressure an important role. These hot solutions may have been formed at great depth and their upward circulation would not necessarily depend upon the difference in weight of two columns of water, as per one of the maps, but the upward circulation could readily be caused by steam pressure or by the enormous pressures of contraction. It would therefore follow that the ore depositing solutions could come from great distances under some conditions, and that the depths from which the waters ascended might depend only upon the depth of the fissures.

The argument, then, of purely local circulation, and from this the statement that ore deposits will not increase with depth, seems hardly warranted for all conditions. Attention has been called to one or two instances where the commercial values have disappeared at depths of 1,000 feet. This is more or less a common occurrence, but it does not follow in all localities that the values may not reappear at greater depth.

The Victor mine at Cripple Creek has produced about $1,500,000 in ore, and at a depth of 800 to 900 feet is practically barren and not producing a ton of ore, yet within 5,000 feet of it is the Independence mine, which in absolute elevation is some 800 feet below, and which has plenty of ore.

The question of ore deposits varying with depth is of fundamental importance to mining men, and it would mean much if one could say positively for any one locality at what depths values would disappear or would be found.

CII.

EFFICIENCIES OF SMALL ELECTRIC LIGHTING PLANTS.

By A. W. Richter and B. V. Swenson.

Read September 6, 1900.

In the course of this discussion the writers will present some of the principal results, data and conclusions derived from tests made upon four lighting plants. The plants are situated in cities the populations of which range from 2,500 to 18,000 inhabitants, and may be considered fair types of electric lighting plants, such as are found in our smaller cities.

Time will not permit of a detailed description of the methods employed in making tests of this nature, and, indeed, it may here be well considered unnecessary; suffice it to say, that the greatest care was taken to obtain accurate results. In the largest plant (station D), duplicate observers noted the weights of coal and water. All data were taken independent of station employes, who attended to their duties as usual, the plant in each case being tested under ordinary operating conditions. All instruments used were carefully calibrated for each test in the laboratories of the University of Wisconsin.

Plant "A" is situated in a city of 5,000 inhabitants, and is a lighting plant purely. It has been in operation for some years, and is similar to a large number of plants now in existence, containing machines and apparatus which, although the best to be obtained at the time of installation, are at present almost, if not entirely, out of date. The boiler room contains two return tubular boilers, having a total capacity of 150 H. P. The apparatus for heating the feed water consists of an open heater, a hot well, and an economizer, a circulating pump being used in addition to the ordinary feed pump. The engine room, Fig. 1, contains a simple Corliss engine, built by the E. P. Allis Company, and rated at 125 H. P., with a normal speed of 100 revolutions per minute. This engine drives a counter shaft, to which are belted the alternators and arc dynamos, each machine being controlled by means of a friction clutch. There are two Westinghouse 133 cycle, 2,200 volt, single phase alternators, each of 40 K. W. capacity; and two Weston shunt wound arc machines, each having a capacity of 20 arc lamps of the old style low tension, open arc type. Between machines A and B, Fig. 1, is a shaft coupling which permits of throwing off the shafting beyond No. 2 machine.

The switchboard is made of pine and reaches from floor to ceil-

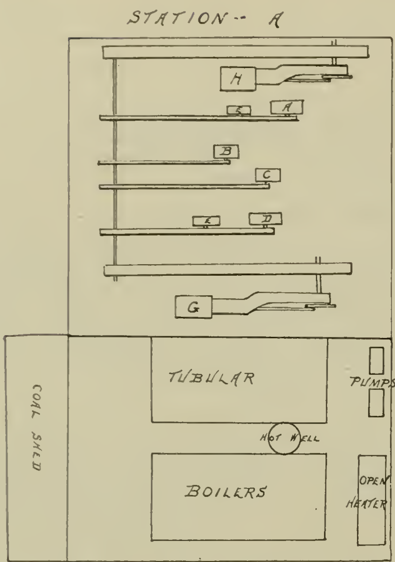

FIG. 1.—A, D, Westinghouse Alternators; B, C, Weston Arc Dynamos; E, E, Exciters; G, Allis Corliss Engine; H, Auxiliary Corliss Engine.

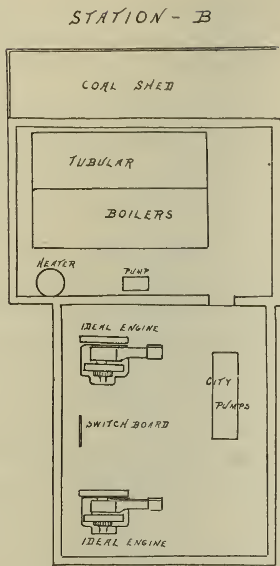

FIG. 2.

ing, the back being completely enclosed. There are two incandescent and two arc circuits. The arc lamps are run from dusk till midnight (moonlight schedule), and the incandescent circuits are on, ordinarily, from twilight until 12 p. m., although it frequently occurs that the plant is operated after this time. The two incandescent circuits are operated independently from the two alternators until late in the evening, when the load falls off sufficiently to permit of both circuits being supplied from the same alternator. The boiler data of this station are not at hand, but the weight of coal and data from engine to lamps are here recorded.

Plant "B," situated in a city of about 2,500 inhabitants, is a combined lighting and pumping plant. The lighting plant has been in operation for about one year, and the entire electrical installation is thoroughly modern. The city pumps are run during the afternoon, just before the lighting plant is put in operation; for the purpose of this paper, only such portions of the station are considered as form a part of the lighting plant. The boiler room (Fig. 2), contains two return tubular boilers, each of a rated capacity of 65 H. P. At present only one boiler is in use at any one time. The feed water flows from the city mains directly into an open heater from which it is pumped into the boiler.

The engine room contains two units, each consisting of a 40

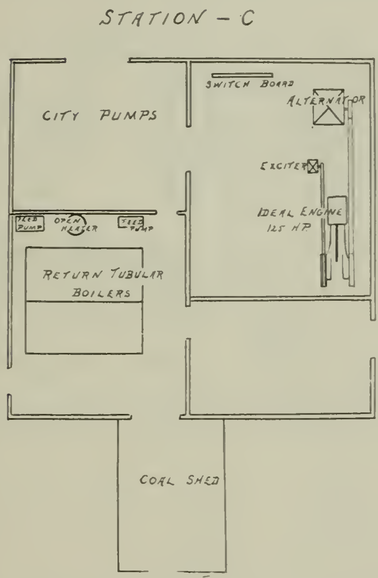

FIG. 3.

K. W., 220 volt, 6 pole, compound wound Westinghouse direct current generator, directly coupled to a 60 H. P. Ideal engine, running at a speed of 300 revolutions per minute. At present, one unit is sufficient to carry the maximum load. A single marble panel switchboard controls both the incandescent and arc circuits. Enclosed arc lamps for street lighting are operated, two in series, across the 220 volt arc mains.

Plant "C," located in a city the population of which is about 3,000, is also a combined lighting and pumping plant. The electric plant is also similar to that of station "B," in that it has been but recently installed and contains entirely modern apparatus. As in station "B," the pumping is done in the afternoon, and only such portions are considered as form a part of the lighting plant.

The boiler room (Fig. 3) contains two return tubular boilers, each of 43 H. P. capacity. The feed water was taken from the main and passed through an open exhaust heater before entering the boilers. The engine room contains a 125 H. P. Ideal engine directly belted to a 90 K. W., 2,200 volt, 133 cycle Westinghouse alternator. The switchboard is a standard Westinghouse marble panel for controlling two single phase feeders, the arc circuit being operated from one, and the incandescent circuit from the other. The arc lamps are of the enclosed type, and are operated from dusk to midnight (moonlight schedule). The incandescent circuit is on from the time of approaching darkness until about 1 a. m.

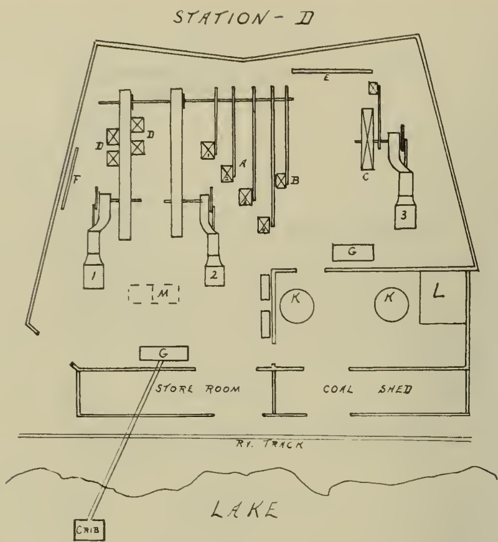

FIG. 4.

A, Arc Light Dynamos; B, General Electric Alternator; C, Monocyclic Alternator; D, Railway Generators; E, Electric Light Switch-Board; F, Electric Railway Switch-Board; G G, Condensers and Pumps; H, Feed-Pumps; I, Oil Room; K, Hazelton Boilers; L, Stirling Boiler; M, Hot Wells; 1, 2, 3, Russell Engines.

Plant "D" is a combined electric lighting and railway station, and is operated during the entire twenty-four hours of the day. The boiler room contains two 300 H. P. Hazelton boilers, one of which is operated each day during the entire twenty-four hours, and one 200 H. P. Stirling boiler, which is "thrown in" from dusk till about 10 p. m. The engine room is equipped with three Russell tandem compound engines, two Davidson jet condensers and heater, and two feed pumps. Engine No. 1 (Fig. 4), of 380 H. P. capacity, is belted direct to the railway generators, and also to a counter shaft. From this counter shaft, power is taken for the arc circuit and for the incandescent circuits during the time of light load. The engine is in operation from 5:30 a. m. until midnight, and supplies the incandescent circuit from 5:30 a. m. to about dusk, and the arc circuit from dusk to midnight. Engine No. 2, of 190 H. P. capacity, is also belted to the counter shaft mentioned above, and is used to operate the arc and incandescent machines from 12 midnight to 5:30 a. m. Engine No. 3, of 400 H. P. capacity, is run at 140 revolutions per minute, and is directly connected to a 300 K. W., 60 cycle, General Electric monocyclic alternator. The alternating current output of the station is used almost exclusively for incandescent lighting, and this unit is in operation during the time of heavy load, from about dusk to midnight.

TABLE I.

GENERAL DATA.

No.		A	B	C	D1	D2	No.
		STATIONS					
1	Kind of Coal used	Locomotive Head End Cinders	Youghiogheny Lump	Indiana Block	Youghiogheny Lump		1
2	Steam Pressure (Gauge)	...	69.5	72.2	120 4	...	2
3	Draught Gauge (Inches of Water)	...	0.17	0.38	0.25	...	3
4	Escaping Gases (Degrees F.)	...	393.0	407.0	561.0	...	4
5	Boiler Feed Water (Degrees F.)	...	176 0	130.0	121.6	...	5
6	Total Coal Consumed, lbs.	...	1296.0	2681.0	21375.0	10300.0	6
7	Moisture (per cent.)	...	1.8	3.2	1.5	...	7
8	Dry Coal Consumed, lbs.	9593.0	1272.0	2595.0	21054 0	10146.0	8
9	Refuse, lbs.	...	74.0	298.0	1923.0	923 0	9
10	Refuse (per cent.)	...	7 8	11.5	9.1	...	10
11	Total Combustible, lbs.	...	1198.0	2297.00	19131 0	9223.0	11
12	Flue Gases (per cent.), CO_2	...	3.6	6.57	9.79	...	12
	O	...	15.5	13.43	10.20	...	
	CO	...	0	0	0	...	
13	Quality of Steam at Boilers (per cent.)	...	99.4	98 5	100.0	...	13
14	" " " " Engine "	...	99.1	98 2	98.4	...	14
15	Total Weight of Water Used, lbs.	...	10484.0	16254.0	157320.0	78000.0	15
16	Total Water Evaporated (Dry Steam), lbs.	...	10421.0	16010.0	157320.0	78000.0	16
17	Evaporation per lb. of Dry Fuel, actual lbs	...	8.20	6 17	7.69	...	17
18	" " " " " " from and at 212° F., lbs.	...	8 78	6 89	8 74	...	18
19	" " " " Combustible, " " " 212° F., "	...	9.32	7.78	9 63	...	19
20	Boiler Efficiency (per cent.)	...	60.1	53.2	65 3	...	20
21	Grate Surface, sq. ft.	...	20.7	31.5	60.9	...	21
22	Coal per sq. ft. of Grate per Hour, lbs.	...	6.71	11.2	14 54	...	22
23	Heating Surface, sq. ft.	...	868.0	1316.0	2906 0	...	23
24	Evaporation per hr. per sq. ft. of Heating Surface, lbs.	...	1.31	1.66	2.25	...	24
25	Standard Commercial Horse Power	...	35.3	65.3	217.6	...	25
26	Builder's Rating	...	57.9	87.8	300.0	...	26
27	Ratio of Commercial to Builder's Rating (per cent.)	...	61.0	74.4	72.5	...	27
28	Duration of Engine and Dynamo Trial (hours)	9 66	9.16	7.33	...	24 0	28
29	Water Drawn from Separator and Steam Pipe, lbs.	...	144.0	370.0	...	1490.0	29
30	Dry Steam Delivered to Feed Pump, lbs	...	384.0	460 0	...	800.0	30
31	Dry Steam Charged to Engine, lbs.	...	9430.0	14863.0	...	75370.0	31
32	" " " " Plant, "	...	9990.0	15683.0	...	78000.0	32
33	Steam Lost by Radiation and Waste, Boiler to Engine, lbs.	...	174.0	407.0	...	2620.0	33
34	Total Indicated Horse Power Hours of Engine	995.0	268.0	457 0	...	3936 0	34
35	Average Indicated Horse Power of Engine	103 0	29.2	62 3	...	164.0	35
36	Maximum Indicated Horse Power of Engine	148.8	51.2	93.2	...	703.2	36
37	Total Watt Hours Delivered at Switchboard	471800.0	148704.0	179350.0	...	2191000.0	37
38	Average Electrical Horse Power at Switchboard	65.5	21.7	33.2	...	122.4	38
39	Maximum " " " " "	96.8	42.2	56.2	...	535 0	39
40	Load Factor (Av. E. H. P. ÷ Max. E. H. P.) (per cent.)	67.0	51.4	59.0	...	22.9	40
41	Dry Steam Charged to Plant per I. H. P. hour, lbs.	...	37.3	34.3	...	19.9	41
42	" " " " Engine " " " " " "	...	35.2	32.5	...	19.2	42
43	" Coal per I. H. P. hour, lbs	9.8	4.75	5.68	...	2.58	43
44	Watt Hours per lb. of Coal	49.4	116.9	66.9	...	212.7	44
45	" " " " " Water	...	14 2	11.0	...	28.1	45
46	Kilowatt Hours per One Dollar's Worth of Coal	89.0	59.5	36.7	...	131.0	46
47	Friction Load (including Excitation Losses), H. P.	35.2	8.2	21.2	...	41.6	47
48	" " (per cent. of Full Load of Engine)	25.1	13.7	17.0	...	...	48
49	Average Efficiency (E. H. P. ÷ I. H. P.), (per cent.)	64.8	74.3	53.2	...	74.6	49
50	Thermal " of Engine (per cent.)	...	6.15	6.60	...	11.20	50

TABLE II.

SUMMARY OF BRITISH THERMAL UNITS.

No.		STATION A			STATION B			No.
		B. T. U.		Per Cent of I. H. P. Hours	B. T. U.	Per Cent of Coal Energy	Per Cent of I. H. P. Hours	
1	B. T. U. contained in 1 lb. Dry Fuel	...	...	...	13410	...	...	1
2	Total contained in Fuel	...	...	...	17058000	100	...	2
3	Brought to Boiler in Feed Water	...	...	...	1507000	8.83	...	3
4	Utilized by Boiler	...	...	...	11756000	68.92	...	4
5	Lost in Chimney, Cinders and Radiation	...	...	...	6809000	39.91	...	5
6	Delivered to Feed Pump	...	...	...	460000	2.69	...	6
7	Lost in Waste and Radiation (Boiler to Engine)	...	...	...	205000	1.20	...	7
8	Delivered to Engine	...	...	...	11091000	65.02	...	8
9	Delivered to Exhaust	...	...	...	10408000	61.02	...	9
10	Converted into Work by Engine	2533000	...	100 00	683000	4.00	100	10
11	Taken by Friction and Losses	886000	...	35.14	175000	1.03	25.75	11
12	Delivered at Switchboard	1647000	...	64.86	507000	2 97	74.25	12
13	Taken by Station Lamps	43000	...	1.80	24000	0.14	3.50	13
14	Delivered to Incandescent Line	1145000	...	45 05	160000	0.94	23 50	14
15	Delivered to Arc Line	459000	...	18.01	323000	1.80	47 25	15
16	Lost in Incandescent Line	426000	...	16.66	23000	0.14	3 50	16
17	Lost in Meter Shunts	...	...	...	21000	0.13	3.25	17
18	Delivered to Incandescent Lamps	719000	...	28.38	116000	0.67	16.75	18
19	Lost in Arc Line	133000	...	5.40	45000	0.26	6 50	19
20	Delivered to Arc Lamps	320000	...	12.61	278000	1.63	40.75	20

No.		STATION C			STATION D			No.
		B. T. U.	Per Cent of Coal Energy		B T U	Per Cent of Coal Energy		
1	B. T. U, contained in 1 lb. of Dry Fuel	12500	...	...	12940	...	...	1
2	Total contained in Fuel	32437000	100	.	131290000	100	...	2
3	Brought to Boiler in Feed Water	1690000	5.21	...	6890000	5.25	...	3
4	Utilized by Boiler	18942000	58.40	...	92620000	70 55	. .	4
5	Lost in Chimney, Cinders and Radiation	15185000	46 81	...	45560000	34 70	...	5
6	Delivered to Feed Pump	536000	1.65	...	1200000	0.91	...	6
7	Lost in Waste and Radiation (Boiler to Engine)	787000	2 43	...	2760000	2 11		7
8	Delivered to Engine	17619000	54.32		88680000	67 53	...	8
9	Delivered to Exhaust	16457000	50.74	...	78610000	59.90		9
10	Converted into Work by Engine	1162000	3 58	...	10020000	7 63	.	10
11	Taken by Friction and Losses	554000	1.71	...	2550000	1 91	...	11
12	Delivered to Switchboard	608000	1 87	...	7470000	5 69	...	12

The lighting machines consist of the above mentioned alternator, and one 100 K. W., 60 cycle, single phase General Electric alternator; also four Thomson-Houston arc light machines, each having a capacity of fifty 1,200 C. P. "open arc" lamps. All but the 300 K. W. alternator are belted to the counter shaft. As the test was complete in all its details from coal pile to switchboard, coal, water, wastes, etc., chargeable to the lighting load were readily determined. The general data here given cover this portion of the load only. The boiler test, however, is also given for the entire plant. In the table giving the general data, Table I, column D_1 shows the complete data for the boiler, while column D_2 gives the general data for the lighting portion of this station.

The boiler performances of stations B, C and D are, as a whole, very good. The flue gas analysis of station B shows a small percentage of CO_2, which is evidence of the fact that too great an amount of air is admitted to the furnace, thereby needlessly reducing its temperature, and also causing a waste of the amount of heat which is required to raise the temperature of this surplus air to a temperature corresponding to that of the flue gases. This might easily be remedied by a proper handling of the fires and draft, 8 or 10 per cent of CO_2 being readily obtained under ordinary conditions, the result being an increase in the efficiency of the plant. In station C the per cent of CO_2 is given as 6.57, which is an average for the day's run, including a test made while firing up one of the boilers. The average obtained during the period of lighting load was about 8 per cent, which must be considered fairly good under the circumstances.

In station A, where locomotive head end cinders are used, a forced draft is necessary to maintain a sufficiently rapid combustion, and consequently a jet of live steam is admitted below the grate for this purpose. About 25 per cent of the steam is used in this way, thereby very seriously affecting the station efficiency, the number of pounds of fuel per indicated H. P. being very much greater than that of either station A or station B, each of which has a smaller output.

During the test of station C, the feed water had an average temperature of 136.1° Fahrenheit, which is below normal, cooling taking place during the time that the water was being pumped into the weighing tanks and weighed. Temperatures of feed water after leaving the open heater were taken on the following day while no other test was being made, and show an average of 208° Fahrenheit, which result is very good indeed.

In stations B, C and D considerable steam was wasted on its way from the boiler to the engine. In station C the steam pipe was uncovered, and in addition it was the custom of the engineer to

allow steam to pass through the drain of the separator. The steam pipe of station D is well covered, but is drained by the use of a steam trap. This trap, like most others, is defective, allowing steam to pass in addition to the water.

The load curves for station A, representing the indicated H. P. and also the electrical H. P. delivered to the lines, are shown in Fig. 5. The incandescent circuit was on from 4:20 p. m. until 2:00 a. m., while the arc machines were running only from 5:30 p. m. until 12:00 p. m. The increase in efficiency (ratio of E. H. P. to I. H. P.) to be observed from 10:00 p. m. until midnight, notwithstanding the decrease in load, is due to the fact that one of the alternators and a portion of the line shafting were thrown off at 9:50 p. m. The low efficiency after 12:00 p. m. is the result of driving considerable line shafting and a partially loaded alternator with a relatively large engine. The low average efficiency (64.8), notwithstanding the comparatively high load factor (average E. H. P. ÷ maximum E. H. P.) is due principally to the poor line shafting and old inefficient machines, to say nothing of an idler between engine and shaft.

Fig. 6 shows the load curves of station B. Here the incandescent circuit was on from 5:20 p. m. until 12:00 p. m., and from 4:30 a. m. until 7:00 a. m., while the arc lamps were burning from 7:00 p. m. until 12:00 p. m only. The combined engine and dynamo efficiency in this case is very good, reaching about 82 per cent at maximum load, and averaging 74.3 per cent, notwithstanding the fact that the load factor is but 42 per cent, this low value being largely due to the long morning run with a very light load. These results show what may be accomplished in this direction in small stations by the installation of modern units of the proper size.

The load curves of station C are shown in Fig. 7, which is strikingly similar, in general appearance, to both Fig. 5 and Fig. 6; and, in fact, all of these figures are typical of the load curves of lighting plants situated in small cities.

It is interesting to compare the curves of stations B and C, since both of them have been but recently installed and contain modern equipment. The maximum combined engine and dynamo efficiency of station C is only about 63 per cent, as against 82 per cent shown by station B, while the average efficiency is only 53 per cent in comparison with 74 per cent given by station B. This difference is due in part to the extra losses of belt transmission and exciter in station C, as against the direct coupled unit of station B, but in a greater measure to the fact that both engine and alternator of station C were at no time heavily loaded, and for a considerable time were running with practically no load except the station lights and the transformer primaries of the incandescent circuit. The effi-

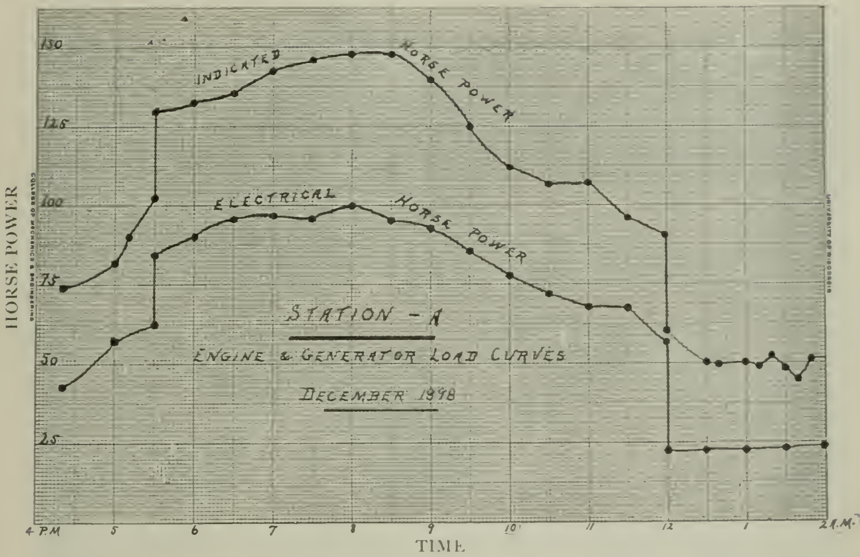

FIG. 5.

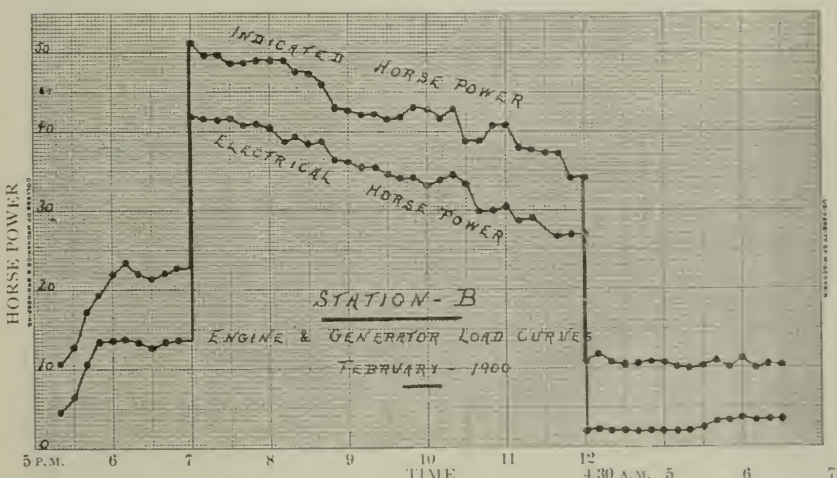

FIG. 6.

ciency of station C might be very much improved by the installation of a smaller unit, to be operated during the portion of the run when the arc lamps are not burning.

Fig. 8 represents the load curves of station D. These curves present quite a different appearance from those of the other three stations, and are such as may be expected in a "twenty-four hour" station.

The incandescent circuit was on throughout the entire 24 hours. The commercial arc circuits were started at 5:30 p. m. and the city arcs were put on between 6:30 and 7:00 p. m. The "all night" city circuit was the only arc circuit running after 12:00 p. m., and it was cut off at 5:00 a. m. The curves indicate a very low load factor and, indeed, it is only about 23 per cent. Notwithstanding this low load factor, the average combined engine and generator efficiency is 74 per cent. This good result is obtained by judicious handling of the machinery; both engines and generators, as far as practicable, running with considerable load during the time of their operation.

Table II shows the results of the tests expressed in British thermal units. The data of station B are given from the total number of heat units contained in the fuel consumed to the energy delivered to the lamps; those of stations C and D are given from the energy of the coal to that delivered to the lines from the switchboard; and those of station A are given from the energy indicated at the engine to that delivered to the lamps. For stations B, C and D these data are reduced to percentages, taking as 100 per cent in each case the heat units in the coal consumed. For stations A and B the percentages have also been worked out, taking as 100 per cent the energy indicated at the engine.

Figs. 9, 10 and 11 represent heat diagrams of stations B, C and D, respectively. Starting at the left, the vertical width of the blackened portion of the diagram represents the number of British thermal units contained in the fuel, which is taken as 100 per cent. The widths of the blackened portions throughout the diagrams represent the proportionate part of the heat units present, the lengths and areas having no bearing whatsoever.

The boiler efficiency is highest in station D, as would naturally be expected, it being the largest plant, equipped with water tube boilers, and handled in the most scientific manner. All three plants have a considerable loss between boilers and engine, due to waste and radiation; a large portion of which might be avoided in each case. As regards the heat units brought to the boiler in the feed water, it is seen that station B has the greatest percentage. Station C would, however, under ordinary conditions, show a percentage of about the same as that of station B, for it is to be remembered that at the time of the test on station C the feed water was considerably below its normal temperature. Station D, being a condensing plant, has a lower feed water temperature than the other two plants, and hence the percentage of heat delivered to the boilers from this source is somewhat less.

As regards the thermal efficiencies of the engines, it is evident that station D is far in the lead, while stations B and C are about

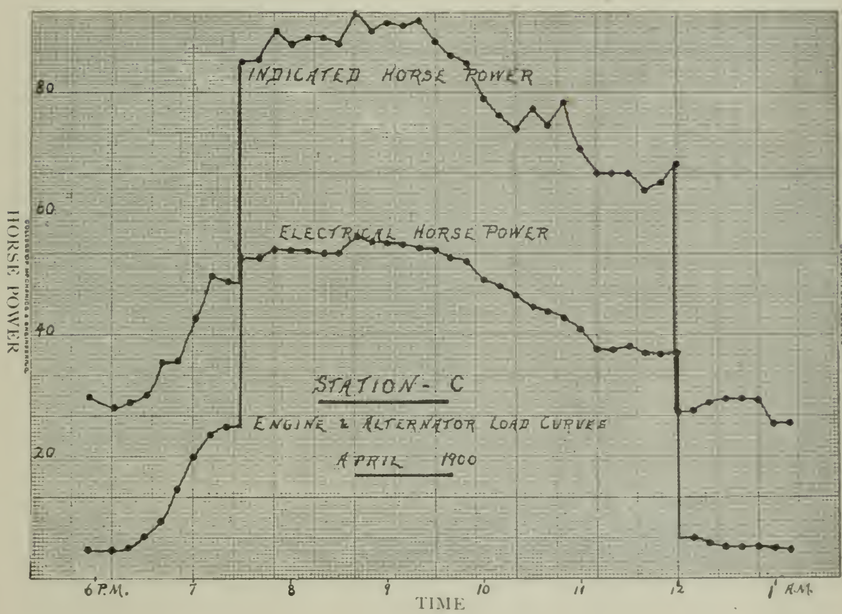
INDICATED HORSE POWER
ELECTRICAL HORSE POWER
STATION - C
ENGINE & ALTERNATOR LOAD CURVES
APRIL 1900
HORSE POWER
80
60
40
20
6 P.M.
7
8
9
10
11
12
1 A.M.
TIME

FIG. 7.

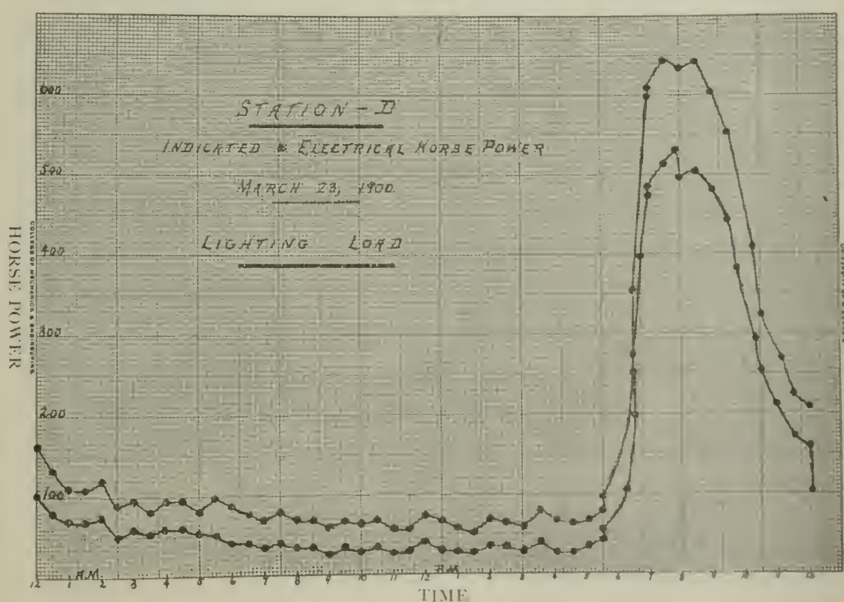
STATION - D
INDICATED & ELECTRICAL HORSE POWER
MARCH 23, 1900.
LIGHTING LOAD
HORSE POWER
600
500
400
300
200
100
A.M.
P.M.
TIME

FIG. 8.

the same. These results are also to be expected when it is remembered that station D contains large compound engines which are always run under comparatively favorable conditions. The engines of stations B and C are of the same make but of different size. Although the one at station B is the smaller of the two, it is run at more nearly its full load, and hence its efficiency compares favorably with that of the larger engine in station C.

Station D again excels in the percentage of energy which is delivered to the line from the switchboard, this percentage being about twice that of station B, and three times that of station C; station B, although having a much smaller output than station C, has a percentage which is one and one-half times as great.

The general good showing of station D is due in no small measure to the fact that station tests have been conducted from time to time, the results of which, in the hands of the chief engineer (who is an active and educated man), have resulted in a steady improvement in its efficient operation.

It is seen from Table I that the pounds of coal per I. H. P. hour are 9.8, 4.75, 5.68 and 2.58 for stations A, B, C and D respectively. The poor showing of station A is largely due to the fact that a considerable portion of the steam generated is used for the forced draught, while the good showing of station D is the result of using well loaded compound engines. The watt hours per pound of coal for the four stations are 49.4, 116.9, 66.9 and 212.7 respectively.

The low value given by station A is to be expected from the large amount of coal used per I. H. P. hour, and also from the fact that the machinery itself is inefficient. The poor result shown by station C is due principally to the fact that both the engine and alternator are very much underloaded. The results obtained for B and D are very good for these respective stations.

A comparison of the kilowatt hours per one dollar's worth of coal in the four cases is more favorable to station A. This is due to the fact that the locomotive head end cinders used for fuel at this station could be obtained for less than one-third the cost of coal per ton in any of the other three plants.

In the tests made upon stations A and B complete data were obtained, from the total energy indicated at the engine to the actual watt hours delivered to the arc and incandescent lamps. The energy delivered to the arc lamps in each case was readily determined by finding the average watts taken by a single lamp and keeping a record of the number of lamps burning. This was a comparatively easy matter, as in both cases the arcs were used for street lighting only. As the meter system was not in use in station A, in order to obtain the energy taken by the incandescent lamps it was necessary to determine the actual number of lamp

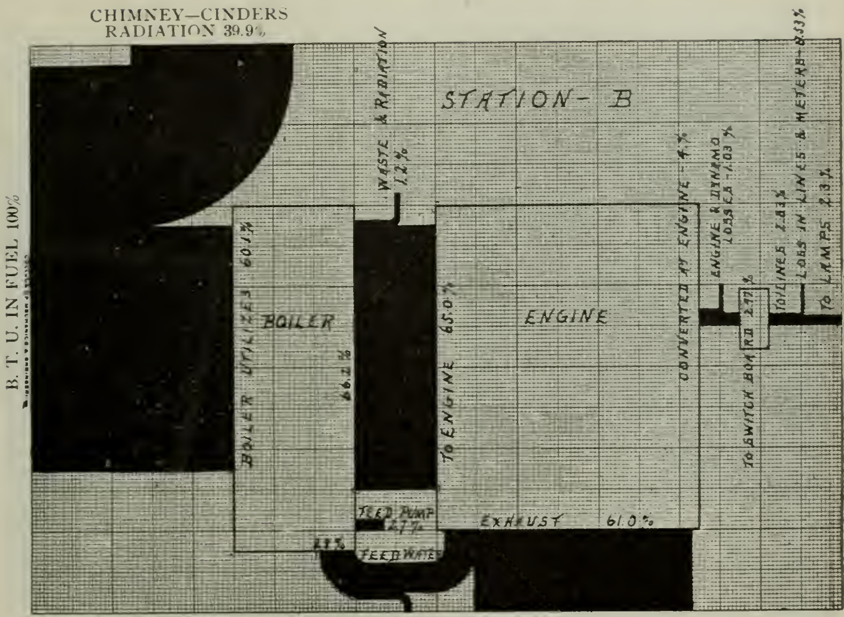
CHIMNEY—CINDERS
RADIATION 39.9%
B. T. U. IN FUEL 100%
STATION- B
WASTE & RADIATION 1.2%
BOILER UTILIZES 60.1%
BOILER
66.2%
TO ENGINE 65.0%
ENGINE
CONVERTED AT ENGINE 4.%
ENGINE & DYNAMO LOSSES 1.03%
TO SWITCH BOX
2.77%
TO LINES 2.83%
LOSS IN LINES & METERS 0.53%
TO LAMPS 2.3%
FEED PUMP 2.7%
EXHAUST 61.0%
FEED WATER
FROM FEED SUPPLY 1.6%
53.8%

FIG. 9.

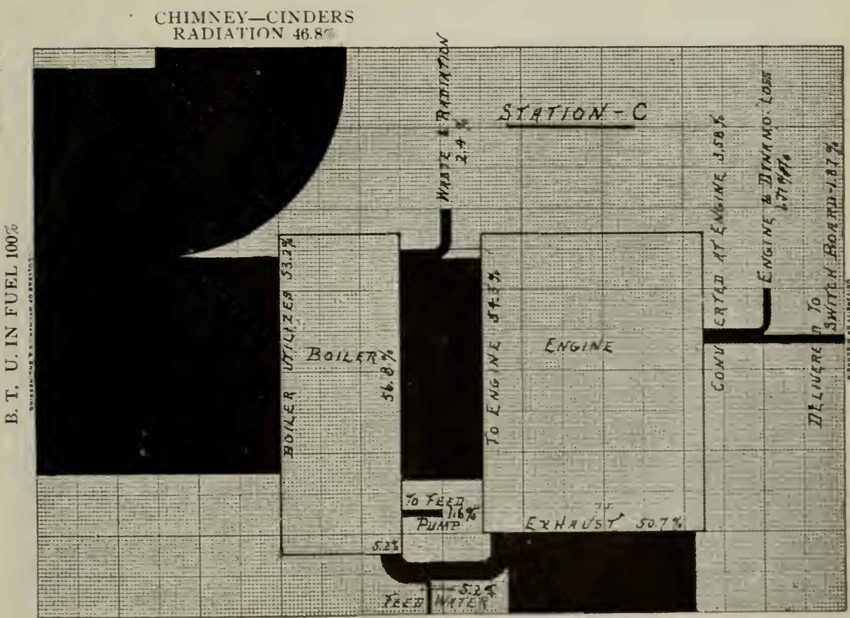
CHIMNEY—CINDERS
RADIATION 46.8%
B. T. U. IN FUEL 100%
STATION - C
WASTE & RADIATION 2.4%
BOILER UTILIZES 53.2%
BOILER
56.8%
TO ENGINE
ENGINE
CONVERTED AT ENGINE 3.58%
ENGINE & DYNAMO LOSS
DELIVERED TO SWITCH BOARD 1.87%
TO FEED PUMP 1.6%
EXHAUST 50.7%
5.2%
FEED WATER
5.2%
FROM CITY WATER 0.9
46.4

FIG. 10.

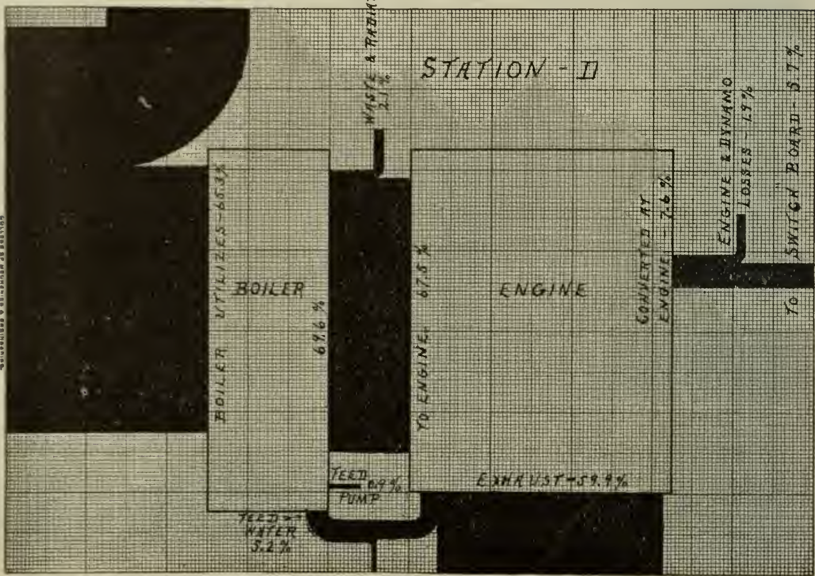

FIG. II.

hours taken by each consumer, and also the average number of watts per lamp. In order to obtain these data as accurately as possible, printed blanks were distributed to all consumers on the day of the test and were collected on the following morning. The blanks were arranged in tabular form for recording the candle power and hours of burning for each lamp, and in addition there was an explanatory note stating the importance of accurate information and showing exactly how the readings should be recorded. As those who use incandescent lighting in our smaller cities are, generally speaking, the more intelligent class of people, and as, moreover, these printed forms were carefully checked where any doubt arose, it is believed that these data are reliable.

Meters were used on the incandescent circuit of station B, and they were read both before and after the test. In addition, the printed form system used at station A was adopted; the two methods checked very well indeed. During the tests at both stations the voltage across the incandescent lamps was taken at various points in the city, and a number of lamps were tested to determine the average wattage per lamp. With the aid of these data the

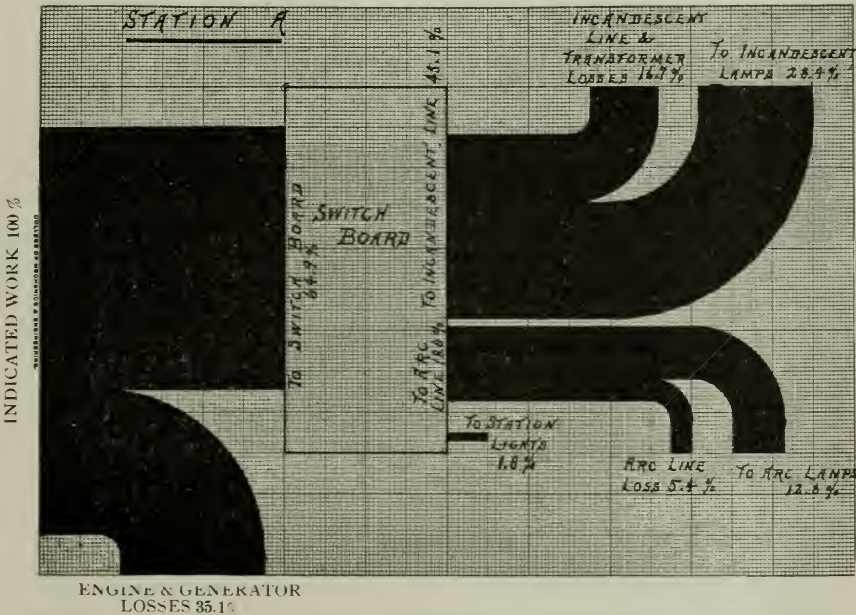
STATION A
INCANDESCENT LINE & TRANSFORMER LOSSES 16.7%
TO INCANDESCENT LAMPS 28.4%
TO INCANDESCENT LINE 45.1%
TO SWITCH BOARD 64.9%
SWITCH BOARD
TO ARC LINE 18.0%
TO STATION LIGHTS 1.8%
ARC LINE LOSS 5.4%
TO ARC LAMPS 12.6%
INDICATED WORK 100%
ENGINE & GENERATOR LOSSES 35.1%

FIG. 12.

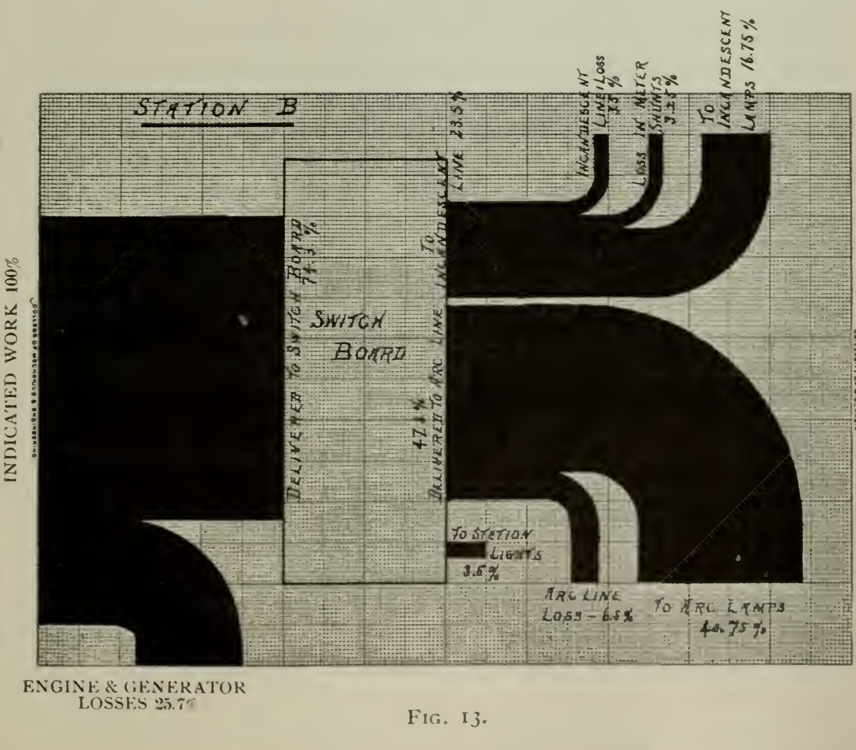
STATION B
INCANDESCENT LINE LOSS 3.5%
LOSS IN METER SHUNTS 3.25%
TO INCANDESCENT LAMPS 16.75%
TO INCANDESCENT LINE 23.5%
DELIVERED TO SWITCH BOARD 74.3%
SWITCH BOARD
DELIVERED TO ARC LINE 47.3%
TO STATION LIGHTS 3.5%
ARC LINE LOSS – 6.5%
TO ARC LAMPS 40.75%
INDICATED WORK 100%
ENGINE & GENERATOR LOSSES 25.7%

FIG. 13.

actual energy delivered to the incandescent lamps was calculated in each case.

A comparison of the heat diagrams (Figs. 12 and 13) shows a very great difference in the losses from engine to lamps in the two cases. In station A very large losses occur in the station itself, due, as previously mentioned, to the poor line shafting and the low efficiency of the machinery. In station B these losses were very much smaller, because of the direct connected modern unit. A further investigation of these two diagrams reveals the very decided difference between the two stations as regards losses from the switchboard to lamps. The very excessive losses in the incandescent line of station A are due principally to the large number of small, old style transformers which are in use. One or more of each size and type were tested for iron and copper losses, and for regulation. In some instances the iron losses were found to be four and five times as much as would occur in modern transformers of the same size.

DISCUSSION.

Mr. J. W. Mabbs—Professor, why is it you get such a vast difference in the amount of waste in the chimneys; so much greater waste in one case than in the other?

Professor Swenson—Station D contained Hazelton water tube boilers in the hands of an educated engineer; the flue gases show a good percentage of CO_2, a good quality of coal was used, and, in short, the results were probably as good as could be obtained under the existing conditions. Stations B and C contained fire tube boilers, in the hands of men of the class usually found in the smaller stations. This is clearly shown by the small percentage of CO^2 present in the flue gases. It has also been stated that D is a larger station and possesses larger boilers. Furthermore, the engineer is required to make a daily report, and as a consequence the boilers are handled in a more careful manner.

Mr. Mabbs—Did station D contain compound condensing engines?

Professor Swenson—Yes.

Mr. Mabbs—And the small direct connected unit of plant C—was that compound condensing?

Professor Swenson—No; that was a 60 H. P. Ideal engine. In station D there were, as stated, three tandem compound condensing Russell engines, of 180, 380 and 400 H. P. capacity.

Mr. J. W. Bley—What kind of coal was used in these different tests? Was it all the same?

Professor Swenson—No. In station A, locomotive head end

cinders were used; in station B, Youghiogheny lump; in station C, Indiana block; and in station D, Youghiogheny lump.

Mr. Bley—What did they pay for those cinders?

Professor Swenson—They pay about $1.00 per ton, as against between $3.00 and $4.00 per ton in each of the other cases. The coal of station B costs $3.85 a ton, put down in their coal shed; station C pays about $3.65 for its coal; and station D pays about $3.25 per ton. I might say in this particular that station D is not the only station that is run by that particular company, and hence they get their coal somewhat cheaper. The price quoted for station D is approximate, but is very close to the actual cost.

Mr. J. W. Mabbs—This subject has been intensely interesting to me, and I have appreciated the paper very much. One thing that surprises me is that the direct connected plant did not show up better; and another thing is, that the Hazelton boilers showed up as well as they did. In the case where they had the condensing plant, did they have water from a river for condensing, or did they use a cooling device?

Professor Swenson—The water was taken from a lake. It has been stated in the paper that station D, which contained the Hazelton boilers, is in the hands of an educated and enterprising engineer, who embraces every opportunity to better the condition of his plant. The direct connected unit of station B, although well loaded at the time of maximum load, was very much underloaded during a considorable portion of the time of operation, the result being a lowering of efficiency.

Mr. Mabbs—There is only one of these plants, as I understand it, that is condensing?

Professor Swenson—Only one.

Mr. Mabbs—That is compound condensing?

Professor Swenson—Yes.

Mr. Mabbs—Were any of the others compound?

Professor Swenson—No; all single. One was a Corliss and the others Ideal.

Mr. Mabbs—In making comparisons, it is rather giving the compound condensing engine plant the advantage over the others.

Professor Swenson—Considering the efficiency of operation only, it is conceded that a compound condensing plant is more efficient than a simple non-condensing one.

Mr. Arthur Frantzen—I am waiting impatiently to see the printed article in order to study it carefully. In matters of this kind it is very hard to pass judgment, but I was very much surprised at the great difference between the energy in the coal and that which goes to the lamps, or even that which is delivered to the engine.

A Member—I think the paper brings out very clearly how far we

are from the ideal that we are working for. The idea of getting, at the switchboard, 3 or 4 per cent of the total heat units of the coal shows a tremendous loss; and these diagrams are particularly happy in showing in this graphic manner the losses through the engine and the dynamo, and the losses through the line, until finally we arrive at the small amount of actual available energy at the switchboard, which is 3, 4 or 5 per cent of the original energy in the coal. I would like to ask what the steam pressures are in these various plants?

Professor Swenson—Plant A, the boiler data of which is not given, has a steam pressure of about 97 pounds gauge; plant B, 69.5; plant C, 72.2; and plant D, 120.4.

Mr. William S. Love—There is one point I would like to make; that is, in station A, which had the Corliss engines and the line in shaft, the loss was 35 per cent, was it not? That is, the loss between the 100 per cent which the engine indicated, and the output from your dynamo was 35 per cent, wasn't it?

Professor Swenson—Yes.

Mr. Love—When you came to your direct connected unit you had only 25 per cent loss; is that right?

Professor Swenson—That was so. We had 25 per cent for the total loss.

Mr. Love—Now, if you call 100 per cent the indicated horse power of your engine, then the loss that you got from that was in one case 35 per cent and in the other 25 per cent. It seems to me that there ought to be a larger difference between a plant with shafting and belting, and a plant in which the engine is directly connected with the dynamo.

Professor Swenson—It must be remembered in this connection that station B, which contains the small direct connected plant, had a very low load factor. Station B had a load factor of 51.4 per cent against 67 per cent in station A. Hence, the difference in the average efficiency is not as great as might otherwise be expected. If they both had the same load factor there would be a much greater difference in the percentage of friction and the dynamo losses in the two stations.

Mr. Love—Then I would like to ask you if you made any test in which you threw the full load on station B, which was the direct connected unit, was it not?

Professor Swenson—Yes.

Mr. Love—Now, assuming 100 per cent as the I. H. P. of your engine, if you had a full load on, what would you get out of your dynamo?

Professor Swenson—We obtained 82 per cent for our maximum

load, which was not quite a full load, although that would be practically full load efficiency—which performance is very good.

Mr. Love—Then did you ever try station A with a full load?

Professor Swenson—Not for a full load, but—

Mr. Love—For a maximum load what do you obtain?

Professor Swenson—It would be a ratio of 96.8 to 148.8, which is about 66 per cent, as against 82 per cent. These would be practically full load efficiencies; that is, combined efficiencies of engines and dynamos.

Mr. Love—Then the loss in driving between direct connected and shafting would be about 16 per cent?

Professor Swenson—No; because this would be true only upon the condition that the engines and generators in the two cases have the same combined efficiency, which is not the case in this instance. The old dynamos in station A would be very much lower in efficiency than the modern dynamos of station B. Consequently, there would be not nearly as much as 16 per cent loss in the line shafting.

CIII.

AN EXPERIMENT WITH WET AND DRY CONCRETE.

By Irving Hitz, M. W. S. E.

Read October 17, 1900.

There is at present a wide diversity of opinion among what are supposed to be our best authorities, as to the amount of water that should be used in mixing concrete.

The authors on this subject disagree radically, and the engineers and building contractors are similarly divided in practice.

To show the diversity of opinion among writers on the subject, I have gathered the following extracts:

Professor Ira O. Baker, in his "Treatise on Masonry Construction," says: "Cements vary greatly in their capacity for water, freshly ground cements requiring more than those that have become stale. An excess of water is, however, better than a deficiency, particularly where a very energetic cement is used, as the capacity of this substance for solidifying water is great."

Mr. Henry Reed, in his "Practical Treatise on Natural and Artificial Concrete," says: "A careful attention to the quantity of water used is desirable if mortar or concrete mixtures are wanted to be of the best character." The author then gives a list of experiments which show that one part by measure of water to three parts of cement gives higher results as to tensile strength than any mixture with more water. He concludes the subject by saying: "These experiments prove, of course, that the least quantity of water used produces the best results."

Mr. D. B. Butler, in his new book published in 1899 on "Portland Cement—Its Manufacture, Testing and Use," says: "The amount of water to be used in mixing concrete depends entirely upon circumstances, and no hard or fast rule can be laid down on this point. As a general rule, however, excess of water is preferable to an insufficiency. If too much water is used it will be impossible to obtain a solid concrete, owing to the space occupied by the excess of incompressible water, while, on the other hand, if too little water is used, the mass will not flux properly and will thus be rendered porous. Of the two extremes an excess of water is preferable as less likely to lead to dangerous consequences."

Mr. John Newman, in his notes on "Concrete and Works in Concrete," says: "An excess of water in concrete mixing is an error, for then the water affects too much the grains of the cement,

which should be merely brought to a gelatinous state, separates the particles of cement and sand, delays the hardening and drying of the cement, and makes it more porous than it otherwise would be." In regard to the tensile strength, he says: "The tensile strength of cement is reduced if too much water is used, and the quantity should be as small as possible, consistent with the proper mixing, as the strength is thereby increased; but, on the other hand, it has been stated by experimenters that this difference decreases considerably with age."

Fig. 1.

It is very apparent from the foregoing that there is far from a unanimity of opinion among writers on this subject.

When we come to actual practice we find the same variance, and from some recent valuable statistics gathered by the Society of Railway Superintendents of Bridges and Buildings we find the following:

Out of 35 of the most prominent railway companies throughout the country, who are using concrete to any extent, ten prefer a dry mixture, five prefer a moderately dry mixture, sixteen prefer a moderately wet mixture, and four prefer a wet mixture.

In view of this great difference of opinion on this subject, and with the idea of confirming, or perhaps changing, its present prac-

tice, the bridge and building department of the Chicago, Milwaukee & St. Paul Railway conducted the following experiment:

Two boxes, each three feet square at the base and three feet high, were carefully made of matched and surfaced 2 inch lumber, as nearly alike as possible. They were then balanced 13 feet apart, center to center, on two 8x16, 16 foot bridge stringers, with a short piece of rail on the under side of each stringer, and a third piece of rail placed across and under the other two at the central point between the two cubical boxes, on which the whole structure rested. (See Fig. 1.) The boxes were then made to balance while empty, by adding weights to the light end, and all was in readiness to receive the concrete which was to be placed in them. In one box was placed a very wet mixture and in the other a dry mixture.

The concrete was made of 1 part of Atlas Portland cement, 3.24 parts of gravel, and 3.65 parts of crushed limestone. The gravel used was composed of 51 per cent of sand which would pass through a No. 4 screen, and 49 per cent of pebbles ranging in size from ¼ inch to 3 inches in diameter. This made the actual proportions about 1 of cement, 2 of sand, and 5 of crushed stone and pebbles.

The concrete was mixed by a Ransome concrete mixer, and all the materials used were carefully measured.

In the box containing the wet mixture was placed 4.38 cubic feet of water, 5.35 cubic feet of cement, 17.32 cubic feet of gravel, 19.5 cubic feet of crushed stone—a total of 46.55 cubic feet, and the box held exactly 27 cubic feet, making a reduction of volume due to voids in stone and gravel of 40 per cent. The 4.38 cubic feet of water added is 82 per cent of the volume of the cement used and made a concrete which was very wet, sloppy and awkward to handle, as the wheelbarrows would hold only a limited amount without slopping over.

When deposited in the box it required no tamping and, when allowed to stand, water would come to the surface. It was purposely given a greater excess of water than would ever be used in actual practice. A part of this excess water escaped through the cracks and over the top edge of the box when filled.

In the box containing the dry mixture was placed 2.05 cubic feet of water, 4.71 cubic feet of cement, 15.25 cubic feet of gravel, and 17.16 cubic feet of crushed stone—a total of 39.17 cubic feet, making a reduction of volume due to voids in stone and gravel of 31 per cent. The 2.05 feet of water which was added was 44 per cent of the volume, or 34 per cent of the weight, of the cement used, and made a mixture which, by repeated very hard tamping could be made to quake slightly, and moisture could be seen on the surface of each 6 inch layer after the tamping was done.

It required 35 minutes to fill the box with the dry mixture and 20 minutes to fill the box with the wet concrete; the difference in time being due to the amount of tamping required to properly compact the dry mixture.

As soon as the boxes were filled the blocking was removed so that the weight of the cubes rested on the cross rail, and by means of the jack screw under one end this rail was shifted until the two cubes exactly balanced. It was found necessary to move the center cross rail 0.30 feet toward the cube of wet concrete to effect a balance. This showed that the wet concrete cube weighed 9.7 per

Fig. 2

cent more than the cube of concrete which had been mixed dry; a difference of about 340 pounds.

When the concrete had set and the frame was removed the difference in the appearance was very apparent. The face of the cube of wet concrete was smooth and compact, while that of the dry cube was full of voids and very rough, notwithstanding the fact that much more time and labor were expended in tamping and depositing in layers the concrete of the dry mixture.

The cubes were allowed to stand on the balance 30 days. Careful observations were taken to see if the loss of the excess water in the cube of wet concrete would appreciably diminish its weight, but no such loss of weight could be observed.

When the cubes were 30 days old they were broken in the following manner (see Fig. 2):

Five ¾ inch holes were drilled about 6 inches deep across the center of the top surface, and two similar holes were placed down

the sides. Ordinary plugs and feathers were then used to crack open the cubes. The same number of holes were used for both cubes, and it was found that the cube of wet concrete was very much harder to break than the other; and the cube of dry concrete broke vertically down to the center of the cube and then the fracture followed the horizontal layer which marked the top of the first batch deposited by the mixing machine. The Ransome mixer contains, when full, about ½ a cubic yard, and there was, therefore, an interval of about five minutes after the first one-half of the box was filled until the rest was put in. This second batch did not make a perfect union with the first one in the case of the dry con-

FIG. 3.

crete, and the cube broke along this line which marked the top of the first batch, at first, and had to be redrilled and broken to get the lower half in two parts.

The photographs showing the broken surfaces (see Figs. 3 and 4) of the interior of these two cubes are not entirely satisfactory, as there was more difference in the real appearance of these two faces than is shown by the camera. The interior of the wet cube was a solid and compact mass, with most of the pieces of limestone and granite pebbles broken across along the line of the fractured cube; while the interior of the cube of dry mixed concrete was full of voids and pores, and a much larger percentage of the pieces of stone and pebbles were pulled out of the opposite side of the fracture, instead of being broken as they were in the wet mixture.

Fig. 4.

This experiment was conducted at 5 p. m. on a warm day, the thermometer reading 80 F., which accounts in part for the large percentage of water used, even in the dry mixture.

The results of this test seem to show:

(1) A moderate excess of water is not injurious.

(2) More labor is necessary in mixing and placing a dry or moderately dry concrete than a wet one.

(3) It is impossible to get a compact concrete without using what is, theoretically, an excess of water.

I believe the practice of using dry concrete to the extent it is used at present has arisen from the fact that laboratory experiments, which are generally conducted on a small scale, under quite different circumstances from the conditions of actual practice, have shown the best results with a minimum amount of water.

The objection that is often raised that an excess of incompressible water must leave voids in the concrete upon evaporation, is not a serious one. The excess of water would not, in actual practice, ever exceed one cubic foot in 27 cubic feet, and, as was shown by the foregoing experiment, there were 2½ cubic feet more of voids in the cube of dry mixed concrete than in the one containing an excess of water.

On exactly the same principle that a hole excavated in the earth can be refilled much more compactly and permanently by the addition of water to the filling than by any amount of tamping of dry or moist earth, so can a more compact concrete be made by the use of a slight excess of water.

DISCUSSION.

Mr. Liljencrantz—I would like to ask if the two cases cited here represent the extremes of the amount of water used, and if there would not be a case between the two that might give a greater satisfaction than either?

Mr. Hitz—Yes; I would say that the wet mixture was wetter than ever should be used, and the dry mixture is dryer than should be used; and that the best mixer is between the two.

Mr. Lee—I would like to ask whether it may not be a fact that, in laboratory tests of that sort, the difference in the strength is due to the age of the test samples? I think that the strength, especially with reference to the amount of water that may be present, is more apparent in short time tests, and that it will probably be found that the longer the length of the time the more the apparent strength of the samples tested approach each other.

It would seem, also, as if there are many laboratory tests which should be received with a grain of allowance, since, as brought out

in the paper, the conditions are not similar to actual work. In actual practice it is necessary to observe the working of the material, and to give a good deal of weight to the manner in which it handles. I think the paper tonight has shown this very clearly. It may be worthy of consideration, also, whether the paper does not show that, within certain limits, possibly quite wide limits, the presence of more water or less water is a question which can entirely be disregarded. The general trend of practical work seems to be toward quite a wet mixture, and mainly for the reason brought out in the paper that, unquestionably, the wet mixture tamps itself, as it were. The question of tamping, everyone will concede, is a very important one in making concrete, and while, theoretically, a concrete which is relatively quite dry ought to be, and, perhaps, with sufficient attention can be, properly looked after, and sufficient tamping secured, yet, as a matter of fact, in practical operation it is almost impossible to secure proper tamping in anything like what might be called a very dry mixture. And this practical consideration would seem to me to be worthy of more weight than all of the laboratory tests, which seem to point in the other direction, toward a moderately dry mixture.

As to the question of whether a mixture can be too wet for practical purposes, it would seem as if the fact that concrete is successfully used under water, and, when put in under proper conditions develops at least an equal, if not a greater, strength than in air, should be a final answer to that question.

Mr. H. P. Boardman—I have heard and read a good deal about the results of laboratory experiments differing from the results of these practical experiments in that the dry mixtures give a much stronger mortar than the wet mixtures. But I have never been able to get such results in my experience with laboratory experiments, and I have made a great many tests, varying the per cent of water, for instance, for neat Portland cement from 11 or 12 per cent up to 30 and 32 per cent; but the one thing I always insisted on was that the mortar, in every consistency, be put into the moulds by thumb pressure, and not pounded in. I never considered that a dry mortar pounded into the moulds could give a fair test of the strength. Very dry cement mortar can be pounded into moulds and a very strong briquette made, but you never get that condition in practice. The hardest tamping you can give the concrete in work, when you consider its effect on the concrete, must be very slight compared with what you get in a briquette, where you have such a small quantity closely confined in a mould upon which to concentrate the tamping. Now, wet mixtures can be compacted no more by pounding than by thumb pressure, because when you press the mixture in one place it yields in another, and the results of the

experiments I have made in that line almost invariably show that the strongest mixture and the one that gives the most dense mortar is wet enough to be plastic, so that it can be readily moulded into any shape. When you press in one part of the mould it yields in another place. That is the general conclusion, both for a natural cement and Portland cement, sand mortar and neat mortar.

In this connection, it may be well to cite the experiments of Mr. Rafter on concrete cubes. He argues that the dry mixture is stronger, and his experiments seem to show that it is slightly stronger in compressive strength. He had three mixtures—the dry, the plastic and the excess. He made a great many 12 inch cubes and they were broken at the Watertown arsenal. The dry mixtures averaged a very little the strongest. But any one of them is so much stronger than is demanded in practice in the ordinary use of concrete, that I don't think the actual strength in compression, as determined by these experiments, should cut very much figure in deciding which to use, when the cost of getting good, dry concrete is so much more than for wet—on account of the difficulty in tamping the dry.

Mr. Liljencrantz—From the fact that one of those blocks broke horizontally, I presume it was the one made with dry cement, was it not?

Mr. Hitz—Yes, sir.

Mr. Liljencrantz—That break, caused by an interruption in the work of only some four or five minutes, indicates the importance of an uninterrupted supply of material throughout the construction of an extensive mass, as, for example, one of the locks on the Illinois and Mississippi canal, where the whole lock chamber is a concrete monolith; and I think Mr. James C. Long might furnish a paper with interesting data on this subject.

A Member—There is one question—that is, whether there is any change in the volume by reason of expansion or contraction of water; whether, after it was dry, it would contract after it had been put up a long while—with a wet mixture, whether there would be any great cracks in the wall, due to a variation of the volume.

Mr. Lee—I cannot give any information as to the difference in the amount of expansion between a dry and a very wet mixture. In the work with which I happen to be connected on a sanitary district, we used a very wet mixture.

The Chair—That was the practice of the sanitary district, was it not?

Mr. Lee—That was the practice at that time. The view of the engineers in charge, as near as I was able to get at it, was that the wetter the better. There was no special reason why they should

attempt to avoid shrinkage cracks, no special damage being possible on account of their presence. In that wall, I may say that there was no special provision made for lines of weakness in the concrete wall, in order that, should shrinkage develop cracks, they would come in special places. It seems to be a growing practice to provide mechanically, so that when the cracks develop, as they seem bound to do in long walls, they may come at a special place and, as nearly as possible, form a vertical line. In much of the wall that has been recently constructed it will be found that a line of weakness has been provided for by bulkheading the wall every 40 to 60 feet of its length. Sometimes a triangular strip is nailed to the face of the form and the bulkhead is brought to the center of that strip, in order to form a joint when the concrete is placed. This seems desirable, because the recess in the face of the concrete hides the crack or at least conceals its apparent effect, as pointing up masonry does so much to decrease the apparent thickness of the joints.

The Chair—Was that the practice in your 16th street crossing work?

Mr. Lee—To what practice do you refer?

The Chair—To bulkheading the wall and putting them in short spaces. These walls were nearly all concrete retaining walls.

Mr. Lee—Yes. When that work was begun, several walls were constructed without the introduction of bulkheads, but it was noticed that large cracks developed, the reason for these craeks being, in great part, the unequal settlement of the ground on account of unequal loading; not on account of the expansion and contraction. But their presence was very unsightly, and later the bulkheads were introduced, in order to form a line of weakness where these cracks would develop. The engineer had a V-shaped joint at these lines of weakness chiseled out. The joints show plainly, but it has had in large measure the effect of concealing the cracks.

Mr. Shnable—I am able to testify as to the effect of very wet mixtures. We built a wall in Joliet, 4 feet wide on top, 6½ to 8 feet wide on the bottom, and about 14 feet high. The inspectors insisted on a mixture practically as wet as slop. The pitmen, while spreading this mixture, would almost sink to their knees. This wall was completed more than a year ago, and no expansion and contraction cracks have developed as yet. In a few places the 3 inch Portland cement mortar has slightly lifted or blistered up. The wall is about 2,500 long and was built in 100 foot sections by three gangs.

Taking up the question of the absolute accuracy of laboratory tests, my experience leads me to think that they are good as fair

indications. We had a case in actual practice where this was demonstrated—the case of a heavy piece of concrete wall being ordered torn down because some Portland cement, used later, was condemned as "absolutely worthless." After about six months service this wall was torn down. By drilling and the use of dynamite, we found that this concrete would generally break up in big chunks as large as that table. As laboratory tests had condemned the cement, it was expected that sledging would break up these chunks easily. As a fact, I have seen three wedges, in a chunk containing a third of a cubic yard, driven their full length with 16 pound sledges, and still not break the chunk up in pieces. Two men during a day would break up about two cubic yards. This indicates that the wall was fairly well built. This mixture was made very wet.

As a result of my experience, I am convinced that the ideal concrete is composed of mortar made as strong as the stone, and enough mortar to exactly fill the voids in the stone. Specifications written to obtain the above results should replace those now in use which arbitrarily fix the proportions of cement, sand and stone, such as one, two and five.

CIV.

THE RIVER AND HARBOR OF CHICAGO.

By R. B. Wilcox.

When asked to present a paper on the Chicago river and harbor the task seemed easy, as the subject is an interesting one, and I promised to comply; but upon realizing how many admirable papers you had heard on the subject in one form or another, I regretted my rashness. Nevertheless, something in the following paper may be of interest.

We will first recount the improvements that have been made on the river and harbor:

The first white men to come to the Chicago river with their boats were the French Jesuit missionaries and fur trade adventurers. Vague rumors, through intercourse with the Indians, had given them an idea of a great river in the west and through the lakes, and this great unknown river they expected to find a navigable water course across the continent.

It was this idea of a waterway that made Chicago and the Chicago harbor.

Marquette and Joliet came here in 1673; and Marquette's map published in 1681 shows a river connecting the Mississippi river and Lake Michigan, and it is probable that he returned this way after discovering the Mississippi river, for in early times, in high water, persons have been known to have passed from the South Branch, through Mud Lake, into the Desplaines and down that river to the Illinois. The first suggestion of a canal found in print is of the date of August 6, 1814. The passage is as follows:

"By the Illinois, it is probable that Buffalo, in New York, may be united with New Orleans by inland navigation, through Lakes Erie, Huron and Michigan, and down that river (the Illinois) to the Mississippi. If it should ever take place (and it is said the opening can be easily made), the territory will become the seat of an immense commerce and a market for the commodities of all regions." The acquirements by treaty with the Indians in 1816 of title to a strip of land from Ottawa to Chicago, covering, in a breadth of 20 miles, the navigable route of the Illinois, the Desplaines, and the portage to the Chicago, was the foreshadowing preparation for the carrying out of this idea.

The projection of the Illinois and Michigan canal was the source from which Chicago received her first impulse, and she is more indebted to the canal and harbor today than anything else. Railroads have, of course, been the great thing, but the canal was Chicago's strength in her infancy. The canal and the harbor were twin enterprises. Without a good harbor Chicago could never become a port of entry, and if there was no clear way of exit into Lake Michigan, the canal would be almost worthless.

In early times, accretions that had fallen to the bottom from ice that piled up in the river's mouth, added to natural formations caused by lake currents, had formed a large sandbar and at times blocked navigation. A map of Chicago and vicinity made by Mr. Sullivan, surveyor for the United States Commissioners, when they were running the lines to mark the lands ceded by the Indians in 1816, showed the main river flowing northeast and east about three-fifths of a mile, to a point about 500 feet west of the parade grounds of Fort Dearborn. Thence it made a complete bend around the fort and flowed directly south between a big sand bank on the east and a marsh on the west, and entered the lake wherever it could, about opposite what is now the foot of Madison street. A small creek entered the main channel from the north about opposite Franklin street, and from the south another stream entered the river near the present Wabash avenue. Opposite Fort Dearborn a small bayou stretched back from the river to the northwest.

The early travelers visiting Chicago talked about a canal and harbor, and admired the portage which separated the waters of Lake Michigan and the waters of the Mississippi river. They must have noticed the impediment to navigation at the mouth of the river.

No movement was made for the improvement of the river's mouth until Fort Dearborn became one of the most famous of the government trading posts. The agent at the United States Indian factory, which was established in 1805, suggested to the government the necessity of clearing away the obstruction, but his idea was a very limited one, as he thought a narrow ditch which would permit the passage of a Mackinac trading boat would be sufficient.

In 1821, H. R. Schoolcraft, secretary of the Indian Commission, visited Chicago and saw the great need of a harbor. In his "Narrative Journal of Travels" he said: "We allude to the formation of a harbor on Lake Michigan, where vessels may lie in safety while they are discharging the commodities destined for Illinois, or encountering the delays which commerce frequently imposes. It is well known that after passing the Manitou Islands there is no

harbor or shelter for vessels in the southern part of Lake Michigan, and that every vessel which passes into the lake after the month of September runs an eminent hazard of shipwreck.

"Vessels bound to Chicago come to an anchor upon a gravelly bottom in the lake and, discharging with all possible speed, hasten on their return. The sand which is driven up into the mouth of the Chicago creek will admit boats only to pass over the bar, though the water is deep enough to allow vessels to lie above. Among the expedients which have been proposed for keeping the mouth of the river clear of sand, one of the most ingenious and, perhaps, practicable, is that of turning the Kononic (Calumet) by a canal of 16 miles into Chicago above the fort, and by the increased body and pressure of water drive out the accumulative sands.

"It is yet somewhat problematic whether a safe and permanent harbor can be constructed by any effort of human ingenuity upon the bleak and naked shores of the lake, exposed as they are to the most furious tempests. And we are inclined to think it would be feasible to construct an artificial island off the mouth of the Chicago creek, which might be connected by a bridge with the main land, with more permanent benefit to the country at large, if not with less expense, than to keep Chicago clear of sand. Stone for such a work is abundant near the entrance to Green Bay, and if built on a scale sufficiently liberal, it would afford convenient sites for all storehouses required."

Mr. Schoolcraft's idea of protecting the mouth of the river was correct, and this has since been accomplished by the building of the government breakwater. The idea of an artificial mouth and giving the river a direct entrance into the lake was first brought out in 1830 by the engineers making surveys for the canal route.

William Howard, in his plan for improving the mouth of the Chicago river, made in February, 1830, proposed to close the original outlet, cut a channel through the sand bank, giving the river a direct entrance into the lake, and build north and south piers extending into the lake south of east.

Correspondence between residents of Chicago, which was only a settlement of less than one hundred inhabitants at that time, and members of Congress called general attention to the improvement of the harbor in connection with the building of the canal. A map was sent to Congress showing the course of the river, the platted section of the town, and contemplated subdivisions. This finally resulted in the first appropriation for the improvement of Chicago harbor, which was made in 1833; the amount was $25,000.

Work was commenced the same year under the direction of Major George Bender. The project consisted in the formation of

a channel of entrance through the mouth of the river between two piers extending into the lake, and between which a channel of 14 feet was to be obtained. Work was commenced on the south side of the river in front of the fort. The first stone was obtained from up the south branch. Ties and timber were cut on the Calumet, and rafted down the river and the shore of the lake to the harbor. During the first year between 400 and 500 feet of the south pier was finished. The north pier was started in 1834, and, as a rule, was kept 200 or 300 feet ahead of the south pier. Major Bender was succeeded by Captain Allen. Captain Allen's map, drawn in 1837, showed that the south pier had been finished from a point opposite Fort Dearborn across the old channel of the river out into the lake a distance of 1,850 feet; 500 feet of the lake end and the bulkhead were unfinished. The north pier had been built out into the lake 1,200 feet, and 700 feet of the shore end was still unfinished. Four hundred feet of pier and a bulkhead on the lake end were projected in order to shut out the outlet sandbars which now extended beyond the end of the pier. Only a small tongue of the old sandbar between the river and the lake remained. The eastern bank of the original outlet was mostly washed away.

It now became evident that the plan for the improvement was wrong. The winds and currents were rapidly depositing sediment and sand in the shape of sandbars which were backing up against the north pier. Within the outer sandbar of 1837, which extended beyond the north pier, two new bars formed. The continued process of deposit filled in the intervening space and the second bar of 1837 became the shore line of 1838. Since the work was commenced in 1833, the shore line had extended into the lake 700 feet along the north pier, and was rapidly pushing farther in that direction. It became evident that the task of protecting the harbor entrance would become a contest between money, and Nature with her forces of wind, wave and currents. The direction of the pier was changed 25½ degrees more to the north; but this plan was no better than the old one. Money was still appropriated at irregular intervals, but was used only in protecting the work already completed, and in dredging out the channel. Vessels were compelled to run one-half of a mile south of the north pier, and then double on a northwardly course in order to enter the river. This frequently caused long delays. Vessels coming south with the north wind would have to come to anchor and wait for the wind to change before they could enter the inner harbor.

Up to and including 1869 the government expended $416,005 in attempting to improve the harbor. In accordance with the same project the city spent $147,167.22 during the years 1863, 1864, 1865

In the index to Reports upon Works and Surveys for the River and Harbor Improvements, 1866–1879, the work done by the city is referred to and commended.

In 1870 the present project for an outer harbor was adopted. This contemplated the construction of an easterly breakwater 4,000 feet long, about 3,300 feet from the shore, and a southeasterly breakwater 3,000 feet long—the protected area being about 455 acres, of which 185 acres were reserved for piers and slips, and 270 acres with a depth dredged to 16 feet for harborage.

In 1878 the project was further modified by an additional breakwater about 5,400 feet long to be placed north and east of the harbor entrance.

Since 1869 the United States government has expended $1,785,-000 on the Chicago harbor.

There is now available $102,875.61 to be spent on harbor improvement as soon as the federal and city authorities can come to some agreement in regard to a dumping ground for dredgings.

Closely connected with the river and harbor improvements of Chicago is the building of docks, and litigation in regard to wharfing property. In August, 1830, the town of Chicago was surveyed and provision was made for a public levee, on the general plan adopted by western river villages, and extended along South Water street. The levee plan was abandoned, as a system applicable to light draft river boats would not do for large lake craft. The location of the levee became a part of the wharfing property. For many years the land fronting on the river in the original town was such a matter of controversy between the city and the alleged owners that no uniform improvements were made. In 1833 the town first defined the wharfing privileges, so that the owners of lots fronting on the river where the streets run down to it might use all but 80 feet for wharfing purposes on payment of $15.00 per year.

In 1835 the canal trustees laid out a strip of land, 120 feet wide, on the south side of the river, into lots and leased them for 999 years. The lessees were to pay a money consideration and an annual rental of one barleycorn. The trustees were required to dredge the river ten feet in front of the docks within four years from the sale of the lease, the lessees to erect good docks, 5 feet wide and 3 feet above the water, within two years from the time of the lease.

Under these and other arrangements a large amount of wharfing property changed hands, and within ten years most of it was in dispute between private parties, the city of Chicago, and trustees of the Illinois and Michigan canal. An act approved February 27, 1847, was designed to adjust these titles and settle the disputes.

Persons or corporations having claims against the wharfing property were to file them in court and to abide by its decision. The city was desirous of having the title to this property settled as soon as possible, as it desired to widen the river in several places, and in order to condemn land it was necessary to fix the ownership.

Power having been granted to the common council, that body, by ordinances passed during 1847–48–49, described the land in detail proposed to be condemned for the purpose of widening the river. Wharfing lots were laid out on both sides of the river from Madison to State street. One of the conditions imposed upon the owners of these lots was that they were to forever keep the docks in good condition and safe repair "for the free passage of persons on foot, and that in no case shall passengers by water be subject to any charges whatever for landing their ordinary traveling baggage and conveying same over said wharf."

These measures had the effect of inducing the improvement of water property, but, up to 1857, there was only about six miles of dockage built along the Chicago river and its branches, including improvements in the way of artificial basins or slips. Excepting in a few isolated cases, dock lines were never established along the Chicago river. In 1865 a survey for the establishment of dock lines from the city limits to the mouth of the harbor was commenced by order of the council. This survey was carried on through the years 1866–67–68. E. S. Chesbrough, who was city engineer at that time, said in this regard: "One important result of the survey thus far is that the south branch could be made 175 feet wide throughout. It was hoped that it could be made 200 feet wide, but owing to existing improvements this would be impracticable without enormous expense, beside it may be doubted if it would be practicable to preserve a sufficient depth of water for navigation, if the width should be much greater than 175 feet, which seems to be the outside limit of what nature designed for the south branch. The lot lines and the original meander lines of the river, both of which are so necessary in making assessments relative to the proposed widening of the river, present peculiar difficulties and require a local knowledge of records and landmarks possessed by a small number of surveyors." In view of the present requirements of the river, it is unfortunate that the idea was never carried out. The records of this survey were lost in the fire of 1871. It is a hard matter today to determine where the dock lines should be in a great many cases. Owners of dock property were allowed to place their docks about as they pleased. Prior to 1890, permits for building docks were issued by the commissioner of public works informally. Since the passage of the harbor ordinance, in 1890, permits have been issued regularly and the dock lines located by

an engineer, but the records are so meager that it is almost impossible to determine any other location than that of existing lines. The result of the old system has been many encroachments on the harbor area, and a narrow river with bad bends in it. In most cases the encroachments are small, but there are some large ones. They have not always been the result of deliberate design, for the owner would build the original dock on the right line, but in time the docks would become insecure and the weight of buildings or earth pressure crowd them forward into the channel. To prevent collapse of a dock the owner may have driven a new line of piles in the river without pulling the old ones, and put on new caps, thus making a new dock line, or, in building a new dock, adopt the line to which the old dock had been crowded forward, thus narrowing and obstructing the channel.

An attempt is now being made to locate these encroachments. The cost of improving and widening the river will be materially reduced by reclaiming this harbor area, as the owners and not the public will be put to the expense of restoring the old dock lines.

The navigable portion of the Chicago river and its branches is today approximately 14¾ miles in length, as follows:

Main river	1¼	miles
North Branch (to Belmont avenue)	5¼	"
South Branch (to junction)	4¼	"
West fork, South Branch (to Western avenue)	1¼	"
South fork, South Branch (to junction)	1½	"
West arm, south fork (to Ashland avenue)	½	"
East arm, south fork	¾	"
Total	14¾	miles

Since 1861, the river has cost the city of Chicago $1,777,401.82 for dredging, engineering and general harbor expense; $307,649.47 for land damages for widening the river at various places; $575,-827.95 for cleaning the North Branch; $34,953.21 for a lighting plant for the purpose of aiding navigation at night, and $3,300,883.71 for lowering the Illinois and Michigan canal. This latter work was undertaken for the purpose of changing the direction of the current of the Chicago river and was completed in July, 1871, by the cutting of the temporary dam which was thrown across the canal at Bridgeport. Quite a strong current was at once created in the canal and an entire change of the water in the main river and the South Branch was effected in about thirty-six hours. The total amount expended by the city, not including bridges or tunnels, is $5,996,716.16.

The first allowance made by the United States government for dredging in the Chicago river was $25,000.00, contained in an

appropriation in 1894. The government has spent in all upon the Chicago river in dredging, removing obstructions to navigation, by cutting off tracts of land where the river was narrow, etc., $650,000. Mr. Liljencrantz told you of these improvements in 1898 when the plan was projected. The Sanitary District has spent on the Chicago river in dredging and widening the river, by-passes at Adams and Jackson streets, engineering expenses, etc., about $1,050,000. This is exclusive of bridges.

The docks along the river have nearly all been built and maintained by private parties and all the slips have been private enterprises; what these have cost is pretty hard to estimate, as there are no records obtainable from which an accurate statement can be made. The dock frontage along the river and its branches, including slips, but excluding street ends, is about 35 7-10 miles. Estimating the cost of these docks at $30.00 per lineal foot (first cost and maintenance), we have about $5,800,000. The total area of the slips is about 3,800,000 square feet. The cost of dredging these out and keeping them dredged has probably been $1,950,000. This is at a first cost of 30 cents per cubic yard, and 25 cents for re-dredging. The value of the land dedicated to the harbor by the opening of these slips may be estimated at $7,600,000. In 1889 the street railway company lowered Washington street tunnel 3 feet, in order to provide a greater depth to the river, at a cost of $150,000. This will give a grand total cost to private parties of $15,500,000. The above statement is probably far from complete and is probably under the mark.

Summing up, we will have spent on the Chicago river and harbor as follows:

Harbor, by United States government	$ 2,201,005.00
" " city	147,167.22
Chicago river, by United States government	656,000.00
" " city	5,996,716.16
" " Sanitary District	1,050,000.00
" " private parties	15,500,000.00
Total	$25,550,888.38

I will now say a few words about the marine interests. The first boats which came to Chicago were the light canoes of the early explorers and missionaries; then came the Mackinac trading boats which belonged to the American Fur Company, and an occasional boat which stopped at the fort on government business. The first sailing vessel which came to this locality was the Tracey, which came with troops in 1803. The Mackinac barges ceased to visit Chicago in about 1830, when sloops and schooners were introduced and commenced to monopolize the lake trade. The first

steamer which came to Chicago was the Walk in the Water; she arrived in 1821. Ship building was commenced in Chicago in 1835; the ship yard was on Goose Island.

In July, 1839, a regular line of steamboats was established between Chicago and Buffalo. At this time steamboats were favorites and until 1841 steam marine held sway over the lakes, but then public opinion changed and sailing vessels became the only thing. In 1846 Chicago was made a port of entry; the tonnage of the district increased rapidly. In July, 1856, the steamer Dean Richmond, cleared from Chicago direct for Europe, and in 1857 the Madeira Pet arrived from Liverpool.

Without giving you a lot of tables showing the movements of commerce by lake, I am going to tell you that our yearly average tonnage for the ten years ending in 1880 was 37 4-10 per cent more than the annual average from 1862 to 1870. During the next decade—1881 to 1890—a smaller increase on the preceding ones prevails, as it was only 27 4-10 per cent, but from 1891 to 1899 the increase is very marked, it being 42 1-10 per cent over the average from 1881 to 1890.

The yearly average number of vessels from 1871 to 1880 shows an increase of 4 3-10 per cent over the yearly average number from 1862 to 1870. The increase during the next ten years was 2 3-10 per cent, but the yearly average number of vessels of 1891 to 1899 shows a decrease of 22 4-10 per cent. These figures are expressive of the increase in the capacity of vessels that carry our lake trade, the average annual cargo for the nine years, 1891 to 1899, being 85 1-10 per cent greater than the average annual cargo for the ten years, 1881 to 1899, and over 200 per cent greater than the average annual cargo for the period 1862 to 1870.

During the past thirty-eight years the greatest number of vessels engaged in the commerce of the port of Chicago during any one year was in 1869, when it was 27,602, and the least number was in 1862, when it was 14,687 vessels.

Last year the total number of vessels for the city of Chicago was 16,174, with a tonnage of 12,599,239. Of this tonnage the Chicago river received 72 3-10 per cent, and the Calumet 27 7-10 per cent.

Average cargo,	Chicago river	656 tons
" "	Calumet river	1,521 "
" "	city of Chicago	779 "

Although the year 1899 was an exceptionally busy and profitable one for the interests of the inland marine, the records of the port show a decrease in the number of vessels of 12 6-10 per cent compared with 1898, and a decrease in tonnage of 16 6-10 per cent.

This may be ascribed to various independent causes, such as the late opening of navigation, the combination of marine interests of the great lakes, and the commissioning in the Lake Superior lumber and iron ore trade of many vessels which heretofore plied between Buffalo and Chicago, resulting in the diversion to the railroads of much of the grain carrying business. To the Calumet river, with its superior facilities for dockage and deep draft vessels, these remarks may be generally applicable, but the real cause of decrease of business in the Chicago river is an inherent one—its limitations as regards draft and width, emphasized the more in a year profitable to the interests of masters and owners by their refusal of our river freights, when paying business can be obtained elsewhere. There is no more patent argument for the necessity of speedy improvement of the harbor conditions of the Chicago river. This is still more marked this year, as the owners of the larger vessels on the lakes have absolutely refused to allow their vessels to come to Chicago unless they can load at the central elevators or the Calumet.

The current in the river since the opening of the drainage canal in January this year has had something to do with the case. Considerable trouble was encountered in handling of vessels, because our pilots, though the best on the lakes, were not accustomed to a current; but they are now becoming used to it, and there is not half the excitement there was at first. As an example, I will cite the case of the Algeria—a barge about 310 feet long and 44 feet beam. She left Armour "D" house on the South branch, just west of Halsted street, loaded with grain and drawing 17 feet 2 inches forward and 16 feet 10 inches aft, at 5:30 a. m., with two tugs—one ahead and the other astern. It was all they could do to get through Halsted street draw, on account of the current. At 22d street an extra tug was taken on ahead, but even then it took 1 hour and 20 minutes to get through the draw, and 35 minutes to go through Canal street. Four tugs were required to pass over the tunnels—two ahead and two astern. The Algeria finally reached the mouth of the river at 2:15 p. m., a distance of about 5½ miles in 9 hours. The tow bill was $468.56. Ordinarily it should have been just a trifle over $200.

The river must be widened, the tunnels lowered, and the center pier bridges removed, or the river, which has already cost over $25,000,000, will fall into disuse as far as navigation is concerned. Great steps have already been taken in this direction. During the last year the United States government has made improvements in the river in the way of widening it at various places. I have been told that the one cut-off at Erie street reduced the price of handling grain from the elevators on Goose Island a quar-

ter of a cent a bushel. These elevators have a capacity of 8,000,-cco bushels. The Sanitary district has already made plans to widen the South branch, from 12th street south, to 200 feet, and contracts for part of the work have already been let. This project will involve the acquiring of 580,000 square feet of land and the building of 15,000 feet of dock. This will help a great deal; but we still have the South branch from 12th street to its junction with the main river, and the main river to its mouth. The North branch can still further be improved by a modification of the railroad bridges at Kinzie street and some of the other bridges farther north.

DISCUSSION.

Mr. Liljencrantz—Mr. Wilcox has gone back in his paper to a period when I did not know much about the Chicago river, a time long before the beginning of my existence.

I would like to ask Mr. Wilcox one question. In making the suggestions at the end of his paper, regarding the necessity for lowering the tunnels and changing the bridges, I would have expected that another suggestion might have been added, namely, the establishing definitely of dock lines along the whole length of the river. There is no law at present authorizing the War Department to establish such dock lines. When the appropriation was made for the improvement of the river by dredging, it provided that this should be done "to within 15 feet of existing docks and wharves." To interfere with existing dock property would have complicated matters materially, and if a sufficient amount of funds had been asked for, to accomplish a work of such enormous proportions, i.e., the widening of the river according to a defined system of dock lines, forming a channel of ample width for a harbor as important as this, I think it most likely that no appropriation would have been made at all. When additional funds were appropriated, for widening the river, a project was prepared with a view to making the channel available for vessels of the larger type (432 feet long by 48 feet beam) by the removal of the most obstructive dock corners, as far as possible, without letting the cost exceed the available funds.

It is not expected that this will make the river what it should be; far from that. It is at best but a makeshift, a temporary improvement, which will prove inadequate before the lapse of many years.

Work on the places proposed to be improved which were described in my paper of June, 1898, has been completed on all but two tracts.

There are, as just stated, two remaining to be completed, one at Hickory street and one at 18th street. The contract was to have expired on the 30th of September of this year but it took a long

time to get titles approved for the land, and much delay was caused during the favorable working season on that account. Work on the two tracts that remain to be improved has been delayed for following reasons. The first, the so-called "Robert Law Tract" is south of 18th street. The land was conveyed and paid for long ago, but the Sanitary District has proposed to remove a large tract behind it and we are waiting for that corporation to secure their strip of land, when the work will be done.

The other tract, between Hickory and Fuller streets, was owned by Mr. Horatio G. Loomis, whose demise was expected daily for a year and a half, he being thus unable to conduct any business, sign any papers or be consulted in the matter. At present the matter is in the hands of his heirs and everything has been done to hurry the work.

I would like to renew the question as to whether it would not be highly desirable to have a well defined system of dock lines established, embracing the whole of the river and branches. There are now dock lines established in places, here and there, but without systematic connection. I think I referred in my paper to the fact that the Chicago river is in one respect similar to most, if not all, the rivers passing through cities of this country. In European cities it is customary to make a lake front or river front, in short, any water front, the handsomest part of the city, but for some reason the reverse is here the rule. People passing from a handsome part of the South side in this city to a handsome part of the North side must pass through a decidedly ugly, and I might say "tough," part of the city.

If the river was improved with due regard to appearances, with docks built of either concrete or stone (preferably the latter if not deemed too expensive); if the water-front, in the heart of the city, contained office buildings, wholesale and retail houses, instead of coal yards and the like, and if the docks were here used for passenger steamers, then our city would be greatly improved in looks and I believe that the value of this property would be sufficiently increased to make the outlay a paying investment as well as a credit to the city.

Mr. Wilcox—Dock lines, as Mr. Liljencrantz says, have been established only in a few places and have not been connected. A survey is now being made under my direction with a view of ascertaining the existing lines. On a map of this survey will be located lines as established by ordinance and old dock lines as far as they can be ascertained from existing records. In this way encroachments on the harbor will be located and the owners of the dock property forced to move back to original lines. The city can then pass an ordinance establishing dock lines according to these old

records and as fast as land is acquired outside of these lines, for the purpose of widening the river, the new line will become the established harbor line by record.

Mr. Artingstall—You spoke of a strip of 175 feet of land.

Mr. Wilcox—That was simply a strip of land for the wharfing lots. Mr. Liljencrantz was speaking of having a fine dock along the river, and with office buildings along the main river, where vessels are allowed to land. The property owners say these docks are a great expense and bring in nothing at all. Two or three owners on whom I have served notices to rebuild docks, have told me that they would would give anything if their property was a block away from the river instead of on it—that it would be worth more money to them. That is because the owners can never rent out the docks along the main river, as by law they shall remain forever an open or free wharf or dock, to be built and maintained in good order and repair by the owner.

Mr. Liljencrantz spoke in his paper of a dock line that was established in 1869 along the south fork of the South branch. Speaking of that will show the trouble the city had in trying to establish dock lines. This ordinance was passed in 1869, and made the width of the river 175 feet along the south fork, and an assessment was levied on the property owners for the benefits and payment was to be made for the land damages, but every property owner went into court and protested against the assessment and defeated it. So the ordinance is still on the books, the assessment was never levied, and the property owners never paid, so the ordinance will not hold.

Mr. Liljencrantz—I thought it was the fire of 1871 that interfered with carrying out the project?

Mr. Wilcox—I have seen a copy of the ordinance and a copy of the plat and everything.

Mr. Artingstall—The survey was made in 1869 or 1870, and I think the plats were there after the fire. They ought to be in the City Hall now, although I have not seen them within the last ten years.

Mr. Wilcox—A survey was made in 1865, 1866 and 1867, but the plats, I have always understood, were destroyed by the fire. Then in 1872, 1873 and 1874 the city spent about $17,000 in a new survey, and those plats are on file in the city engineer's office.

Mr. Artingstall—There was another record made by, I think, Mr. Jenney, who was chief engineer of the Illinois and Michigan canal, about the South Water street property between State street and Lake street, in connection with the water front. He states that all that property between the river and South Water street belongs to the state of Illinois, and I think you will find that in

his report to the Illinois and Michigan canal commissioners. It is public property for wharfage purposes alone.

Mr. Wilcox—I always understood that the act of 1847, by the state, gave the city the right to lease these lots to the lessees to put up buildings, with the condition that they maintain a dock five feet wide.

Mr. Artingstall—It is canal commissioner's land, and Mr. Jenney shows it. If you will get the report of the Illinois and Michigan canal, I think you will find the present owners haven't got any title.

Mr. Wilcox—I might give you an example of an encroachment upon the river. I think I can prove by the records that at one place on the river the dock should be 205 feet from a certain street, and yet to-day it is 230 feet, but we have to go back to the records of 1835 to prove it.

Mr. Lee—I would like to ask if the falling off from 1879 was on account of a change in the Chicago commerce.

Mr. Wilcox—I think it is. Vessel brokers here in the city tell me that they have written to owners of boats saying: "We have grain here; will your boat come and get it?" "No, sir; if you have grain you can load it at the Illinois Central elevators, at the mouth of the river, or the Calumet, but we will not send the boats up the Chicago river." Mr. Hanley, superintendent of the Armour elevator interests, has told me that it is practically impossible to get boats of large size to go up the river now.

Mr. Lee—Isn't that also true of the Calumet freights in 1899—falling?

Mr. Wilcox—Yes, but it was not as much as in Chicago. There was a falling off of the Calumet and that was because boats were diverted to the Lake Superior lumber and iron ore trade, but there is no trouble in getting large boats to go to the Calumet to load with grain. These large boats will earn $7,000 in about four days. If they have to come to the Chicago river and spend nine hours in going five miles (they could run to Milwaukee easily in that time) they will never come.

Mr. Liljencrantz—Mr. Wilcox spoke about docks having been repaired by building out in front of old docks. I can testify to the truth of that statement. In rebuilding several of our docks we found front-piles from the old ones, three and four feet and even more back of the existing docks.

The Chairman—Can you tell us how far the authority of the federal government extends over the matter of the dock lines?

Mr. Liljencrantz—As before stated, the War Department has not been authorized to establish dock lines. In carrying out an improvement we must be guided by the wording in the river and

harbor bill. When the dredging was authorized it was provided that it should be done so as to enable vessels drawing sixteen feet of water to navigate the river, and that it be done to within fifteen feet of the existing docks and wharves.

The Chair—You can't compel a greater channel than 16 feet?

Mr. Liljencrantz—That was the provision in the first bill, when the appropriation was made for dredging. In the last river and harbor bill the legal depth for the Chicago river was established at 21 feet, but with the provision that no work should be done until the tunnels have been lowered and the center pier bridges changed to bascule bridges by, and at the expense of, the city.

The Chair—What is the depth over the Washington street tunnel?

Mr. Liljencrantz—Seventeen feet.

The Chair—Is that the shallowest part in the South branch?

Mr. Liljencrantz—It is. The crown of La Salle street tunnel slopes down to 18 feet in the center.

Mr. Artingstall—You say the tunnel is 17 feet below city datum?

Mr. Wilcox—That was the original plan, to make it 17 feet in the center and 16 feet at the dock line. The crown of the tunnel was taken off except where the center pier of the bridge stands.

Mr. Artingstall—Yes; taken off and a new one put on. We had to build a new crown at the center pier for the bridge, and it is higher. It is 17 feet at the center pier on each side, and 16 at the dock line. That is the shallowest. At Van Buren it is full 18 in center and 16 at dock. At La Salle it is about the same.

Mr. Liljencrantz—I should like to ask if Mr. Wilcox can tell how many docks, now in existence, excluding those built by the Government, could stand a depth of 21 feet in the channel if dredging is done nearer than 30 or 40 feet from the dock?

Mr. Wilcox—I should say from one-quarter to one-third of the whole length.

Mr. Artingstall—The river in some places is not more than 140 feet wide.

Mr. Liljencrantz—Perhaps I ought to put the question more definitely by asking: Can Mr. Wilcox state the approximate amount, in lineal feet, of docks that could stand a depth of 21 feet to within 15 feet of them?

Mr. Artingstall—You are asking a pretty hard question.

Mr. Wilcox—I think he is, too. For the last two or three years we have been very careful and watched every owner building a dock, and we have required him to use thirty-foot sheeting. I think under these conditions they would stand, but along the main river up until this year, I don't think there was a dock that had sheeting over 18 to 20 feet long. On the south side of the main

river, almost the entire length of the dock has been rebuilt this year with 45 and 50-foot piles and 30-foot sheeting.

Mr. Artingstall—How high above the water are the piles—stand about 5 feet?

Mr. Wilcox—No; along the main river the piles are one foot above the surface of the water, and then built up with crib work. I think that during the last year I have served notice on nearly every property owner, where I knew the Sanitary District was not going to build a dock, to rebuild, and in the notice I stated that they must provide for 21 feet of water.

Mr. Liljencrantz—Do you stick to the answer of one-third with that proposition of 15 feet from the dock—now existing—not what is going to happen, but I mean what is now, the line of the docks now in existence?

Mr. Wilcox—It will hardly run one-third. I could not tell off-hand how many feet of dock have been built within the last two or three years. I should say in the neighborhood of about 20,000 feet. That would hardly be a tenth of the total dockage. But then, while there are about 35 miles of dock, a great deal of the distance is slips, and of course the slips should not be taken into account.

Mr. Artingstall—You can't control the docks and slips on private property.

The Chairman—Isn't it a fact that in dredging the Chicago river, the companies that get the contracts are usually dock builders and that they make it necessary to get close enough to the dock to rebuild it? That has been my experience.

Mr. Liljencrantz—I regret to say that they do generally get as near to the docks as they can. I never thought of it in the light you intimate, but it does not seem unlikely. I thought it was to get as much dredged material as possible. I have heard many complaints about the violation of the rule in this respect. Speaking of the length of the sheeting used, we found near Halsted street, sheeting only about 12 feet long, and front piles only 20 and 21 feet. You asked to what extent the Government controls the river. Docks cannot be constructed without a permit from the Secretary of War, but that refers only to those in the main channel. If docks are to be built in any of the slips, permits are not required.

The Chair—I think it is the south and north branches, as well as the main river.

Mr. Liljencrantz—The limits within which the Government has assumed control is from the harbor to the forks at Lake street, in the North branch to Belmont avenue, and in the South branch to the Stock Yards. The Government does no dredging except in the

main channel of the different branches. Construction or reconstruction of bridges also require permits from the Secretary of War. In a general way the Government also exercises control over anything that will affect the navigation of the river.

Mr. Wilcox—In speaking of the length of the sheeting that was used along the main river, as I said, when we came to build up some of the old docks, we found that the sheeting was not over 18 or 20 feet and the piles had absolutely no anchorage. The result was that a great many of the commission houses, this year, have had to put in entirely new foundations under their buildings. As fast as I condemned a dock they would start in to rebuild, and the building department would serve notice to put in a new foundation.

Mr. Artingstall—I would like to ask Mr. Liljencrantz a question. What is the depth of water in the mouth of the river, and is there a bar there at the present time?

Mr. Liljencrantz—There is a bar at the present time, east of the north end of the easterly breakwater, but at the entrance to the harbor there is a channel 300 feet wide that has 18 feet of water.

SECOND DISCUSSION.

Captain J. S. Dunham—I will try to speak a few words as to what I know in regard to this river and harbor question and the commerce of Chicago.

I came here to Chicago in 1854; I was at that time connected with the vessel commerce of Chicago and harbor, and I have been connected with it ever since, more or less. In 1854, I am quite sure that the arrival of vessels in the port of Chicago was not 500; though I have no figures to substantiate me. I have seen that increase to over 12,000, during the season of navigation of about eight months. And I have seen this latter figure decrease to 6,000, which is about the number which we will have this year. Last year, I think it reached a little over 6,000.

The press and the people, a great many of them, say that there is no decrease here in Chicago of the river's commerce. I will say to you, gentlemen, that I think we are losing it very fast. We have but very little lumber coming here now; you might say, only enough for home consumption. One cause of this, of course, is that the forests have all been cut off, and there is not the lumber to come here. But there is considerable lumber that could come to Chicago still. At one time, we were the depot for the distribution of anthracite coal in the western country; coal came here by vessels and went directly into cars, and the whole west and southwest were supplied from Chicago. There is none of that movement from here now, to speak of. It is the same with rail-

road ties. That has been one feature of our business. The grain has always been a great feature in Chicago commerce. I think we have increased the amount of grain that has been shipped from Chicago; that is, when you include the port of South Chicago.

The reason why the people and the press say that our commerce is not decreasing, is because they take the tonnage of vessels arriving here or clearing from here. Years ago, or a very few years ago, all the tonnage that arrived and departed from this harbor took freight. Since that time, we have had a great many passenger boats built, or boats that have gone into the passenger boat business. The number of the passenger boats is counted the same as freight, so that the arrivals and clearances of these today (or it is so in the summer time) are in tonnage about one-quarter of the whole. So that it keeps up our tonnage records from the custom house the same as though it were a matter of business, while it is merely, you might say, a matter of pleasure. So that you can see that our business must be decreasing all the time, even if we do keep up our tonnage. But I am sure that our commerce of the Chicago harbor is decreasing very fast.

There is another circumstance in connection with this decrease: In 1897 a very large firm that owned elevators at South Chicago shipped out a great deal of grain from South Chicago. I think in 1897 they shipped 80 per cent of their business by vessels and 20 per cent by cars. In 1898 they reversed that—made it 80 per cent by cars and 20 per cent by vessels. Their tonnage at that time was very large in grain, for that one particular firm did a very large business. We have a firm in Chicago this year that owns eight or nine elevators, and the vessel agents, who are well posted, inform me that they control about all the grain of this country that is being shipped east. The business has taken a different form. That same firm owns elevators in Milwaukee; they are not shipping much there. But it is a circumstance that it is controlled by one firm, and the very moment that that firm feels that they don't want to take hold of this speculation or ship grain (they find it more profitable to store it in their elevators), the very moment they feel they don't want to ship any more (which firms do do, they ship one year and next don't do anything), I claim that our tonnage here, at least so far as grain is concerned, will decrease very materially. I attribute all to that one firm, the fact of the enormous amount of grain that is being shipped out of Chicago this year. I think there will be more grain shipped from Chicago this year than ever was shipped before. But that is about the only business we have for our vessels in Chicago. Of course, anthracite coal comes here, but nearly all of it is for home consumption.

There are a good many things which contribute to the decrease

of our Chicago commerce, and they have been so widely discussed that I don't think it would be proper for me to take your time here discussing those questions. I will say that I believe that if there isn't something done toward relieving the conditions of our commerce we will wake up some morning and find that we have none left.

It has been thought that the marine interests are very much interested in this question. I want to say to you, gentlemen, that the marine interests are not interested in this question. That may surprise you. Our vessels are what you might call, and are called on salt water, "tramps." We are always ready to go to any point where it pays the best—where we can make the most money. We prefer to go to Lake Superior, and we prefer to go to any other port than Chicago, on account of the delays here and the obstructions and the trouble in navigation. I will say to you, that all vessels prefer to go to most any other port than Chicago. And when you say that it is the marine interests that want the Chicago river improved, I will tell you that we have but very little interest; and I might say to you that as far as our personal interests are concerned—that is, our vessel interests—we don't care. It is to Chicago's interest to make it to the interest of the vessels to come here. Chicago is like any business man—it must reach out, it must retain its business, it must look for business, it must encourage business, and the course it is taking now seems to discourage business here.

The press has taken hold of this question and is encouraging improvements in every way to retain our commerce. The great question now is the tunnel question. Vessels draw, as a rule, 8 to 10 feet without cargo. With from 8 or 10 feet to 16 feet, they carry, maybe, one-half of a load or one-third of a load (that is, large vessels), and at from 16 to 20 feet draft they will carry two-thirds more, or about double; or, in other words, the last foot of draft to a vessel is her greatest carrying capacity, and it is the depth that vessels want. The government has made a contract to deepen the water to 40 feet in New York harbor. By the time that is completed, I believe we will have vessels on salt water a thousand feet long. We have vessels there now that are larger than the Great Eastern, which you all know about vessels over 700 feet in length. It is only the draft of water we want. The great advantage of large vessels is, that it costs but very little more to run the large vessel than it would a small one—but very little; and unless Chicago makes conditions such that those large vessels can come here, other ports will do the business cheaper than Chicago—and you know that business will follow the lines where it is done the

cheapest. It is impossible to stop it, and when your business is once gone it will never return. You are dealing, we will say, with a tailor; he always has given you satisfaction; he suits you in every way, shape and manner. Along comes a competitor and wants to make a suit of clothes for you. "Can you make it," you say to the tailor, "any cheaper than the man I am trading with?" "Well, yes; I will do it so much cheaper." You deal with him. After you have once dealt with him, and he gives you satisfaction, the other competitor comes along, and you say the same thing to him, "Can you do it any cheaper than the man who is making my clothes now?" He says: "No; but I will do it just as cheap;" and although you used to trade with him you will say: "No; I am satisfied where I am now." In other words, the business is here, and to get it away our competitor has to do it cheaper. After they once get it, to get it back we have to do it cheaper than he does.

Mr. J. G. Keith—There can be no difference of opinion among practical people as to the obstacles in the way of commerce on the Chicago river. And while our city has grown to the gigantic proportions of which we are all so proud, our harbor and river, which have contributed to this enormous growth, have been neglected and efforts made toward their abandonment.

Fifty or sixty years ago, when our city was but a village, Chicago river was staked out to accommodate craft of about 100 tons burden. As Chicago and its commerce grew larger our river became smaller, for owners of river property built their docks as they pleased, without regard to dock lines. As docks gave way with time, and were replaced with new ones, the latter were usually built outside of the old to save the expense of removal until today, accordingly, due to this and more avaricious causes, our river at various places is 20 and 30 feet narrower than it originally was, and is obstructed by center pier bridges in addition. Meanwhile our lake craft has increased from 100 tons to 8,000 tons burden, although the greater size is barred from Chicago. Half this size, or about 4,000 tons, is the largest sized vessel that our river will accommodate, and that only for about one-third of its length. Other cities, with much less pretensions than Chicago, make better provision for their marine commerce than we do. Towns of but a few thousand inhabitants, with no better natural advantages than Chicago had, and almost unknown outside the limits of their county until the increase of their harbors, which now admit the largest craft, are now not only known to the United States, but throughout the world wherever iron is a factor in commerce. I refer to Conneaut, Ashtabula, Fairport, Lorain, and other places.

It is a well known fact that to move heavy commodities cheaply

they must be moved in large quantities. Our largest freight carriers and railway companies' ships are rapidly increasing in size, and with this increase a corresponding decrease in freight rates is the result. Within the last three decades lake craft have advanced from 1,000 to 8,000 tons, and from sail to steam; railway car capacities have increased from 10 to 50 tons, and the speed of a freight train now about equals that of a passenger train 30 years ago. At that time freight on corn from Chicago to Buffalo ranged as high as 25 cents per bushel, and as much more from Buffalo to New York. In fact, Mr. B. P. Hutchinson has told me that he has paid 55 cents per bushel on corn from Chicago to New York. Now it is not uncommon to ship corn from Chicago to Liverpool for 7 and 8 cents per bushel, and, even at this rate, it tasks us to meet the markets of the world.

To show a comparison of freight rates as between the two leading freight carriers, ship and rail, may not be out of place here. I remember, some nine or ten years ago, attending a deep waterways convention at West Superior. I there had occasion to compare rates between lake and rail, and found the following figures: The distance from Buffalo to Duluth by water, is practically 1,000 miles; freight on coal was 40 cents per ton. The distance from Duluth to Bismark, by rail, is 500 miles; freight on coal was $4.50 per ton. The freight on wheat from Bismark to Duluth was 16 cents per bushel by rail, and from Duluth to Buffalo 2¼ cents, by water. For half the distance rail freight was eleven times greater on coal and seven times greater on wheat. I make mention of these facts to call your attention to the difference between water and rail and between modern and the older freight methods on both water and rail. Without cheap transportation our western country would be valueless except for stock raising or some kindred industry where large values would be confined to small weight and high freights, a small percentage of the value of the goods; and heavy products, such as wheat, corn, lumber, iron ore, etc., which have made our western world famous, would remain without development.

You may ask what has all this to do with this little dirty, narrow, crooked, tortuous creek, taking upon itself the dignity of a river—a cesspool for 1,700,000 people; a dumping ground for scavengers, stolen and filled up by abutting property owners, shunned by good citizens and scorned by the d——l, forgetful that this same waterway, whatever be its color, was chiefly instrumental in making and maintaining Chicago. On this stream millions of tons of freight are annually moved, and it, with its lake connections, keeps the railroad rates in subjection; without it we might be in

the dilemma that Bismark or any other inclosed town is without water connection.

What we want is a larger harbor and river to admit our largest lake carriers, whereby we can ship and receive our goods as cheaply as do our neighboring towns. We cannot do this at present. We are patronized only by the smaller sized craft which cannot carry freight as cheaply as can the larger, which trade to Duluth, Manitowoc, Sheboygan, Milwaukee, and even our own child—South Chicago. At all of these harbors it is less expensive to receive and ship freight than at Chicago. Our life blood is being sapped by the small places, and we don't know it. We have plenty, and feel it lightly at first; but with freight on corn and wheat, for example, ½ cent per bushel against us and in favor of Duluth, as was the case the greater part of this season, whereas formerly this difference was in our favor and against Duluth, we will feel it heavily. A few more years like the present and it will be painfully felt, and that, too, when the disease gets beyond a cure.

Very properly it may be asked what has been the cause and what the remedy, this year more than others? To this I would reply that the current caused by the opening of the drainage canal increasing tow bills 25 to 50 per cent; and damage bills, delay and short cargo owing to shallow water over the tunnels (particularly Washington street tunnel) deter vessel owners from sending their craft to Chicago unless at a figure to reimburse them for some of the foregoing evils.

The remedy is: Lower the tunnels, remove all center pier bridges and widen and straighten the river. As a consequence terminal charges will be reduced, and vessel owners will then be invited to come, instead of repelled as now. But to make these changes will require years, and as the street railway's tunnel franchise does not expire for two or three years let it be so, and immediately after the close of navigation set about taking out Washington street bridge. By so doing we will gain 9 or 10 inches of water and about 8 per cent of cargo, which would be nearly clear gain to the owner. With this gain in water much of the present evil would be overcome. To this the objection is raised that a new bridge cannot be built until after the tunnel is lowered, as it would interfere with the foundation, and in the meantime Randolph street bridge is ordered out and will be replaced by the time the tunnels are lowered. I would say let Randolph street bridge remain, as it forms but little obstruction, and take out Washington street bridge and give us immediate relief, and not hold up the commerce of Chicago river for three or four more years to preserve the use of Randolph street bridge to the street railroads for the space of six or eight months while a new bridge could be built. Lake street

has two lines of cars on one side, only 400 feet distant, and Washington street on the other, with a car line a like distance, and the inconvenience could not be seriously compared with the accommodation to the marine interests of the city, with their one thoroughfare only, where millions of tons of freight pass yearly, and which would have to suffer three or four, and, perhaps, five or six years more before the tunnels are lowered and a new bridge built. It should be the effort of every good citizen, with Chicago's interest at heart, to have Washington street bridge removed at once.

Mr. L. E. Cooley—I agree with the diagnosis made by Captain Keith and Captain Dunham. I do not think that they stated the case against Chicago half strong enough. It seems to me that they propose to treat symptoms, rather than causes, to a certain extent.

In 1891, at the time I was chief engineer of the Sanitary District, I made a special investigation of the harbor question and shipping interests. I found a water business of some 11,000,000 tons. About 1,000,000 tons of this was I. & M. canal, but something like 10,000,000 tons of actual freight was by lake. The total rail freight originating and terminating in Chicago was about 22,000,000 tons, so one-third of the total freight was water freight, and two-thirds was rail freight. And it seemed to me that water commerce was one lung of the life of the city of Chicago, and that our harbor facilities must be improved at whatever cost, and the question of a remedy gave me very great concern. The Sanitary District did not have the funds to reach this question while I was a trustee, but I took pleasure in my last year of office in pigeonholing the report in accordance with which, later, this river has been *improved*. I use the word advisedly. It was perfectly obvious that it did not comply with the requirements. I don't know that we need be critical in view of all the circumstances—a post-mortem examination may not be profitable—the people have condoned it, and would rather see clean water running through the river and take their chances on the shipping.

I followed this question of water commerce for several years. In 1891 the freight eastbound by water was about equal to that by rail. It kept a little ahead for several years, up to 1896 or 1897, but the last two or three years are unfavorable. As both speakers have remarked, the water commerce of Chicago, relative to other ports, is falling off, and I believe the facts have been correctly stated.

I remember that in 1870, I think, we had the maximum number of vessels, with hand-turned bridges. The number of vessels has decreased, but the size of the vessels has increased very rapidly,

and the total tonnage has shown a healthy point up to the last year or two.

I recall that in 1878, when Chesborough was still city engineer, having some discussion with him. It seems that he made a survey of the Chicago river prior to the fire for the purpose of establishing the dock line for a river 300 feet wide. That survey was repeated after the fire, and then we had a right of way here by which we could make the river any width without infringing on any improvements. But he could not get the Board of Public Works, at that time, to consider the question; the city was poor and could not afford it, and he was asked to wait until it got richer, and I suppose we have now arrived at that time, when we are richer. And we will have to do something if we want more commerce.

Now, excepting the sanitary canal, which is a very notable exception, I don't think the people of the City of Chicago have shown any great enterprise or great solicitude in looking after their public improvements. In nearly every other city you will find a Chamber of Commerce for the purpose of looking after the public interests, and they agitate and make projects and go to Washington and get items in the river and harbor bill, and they keep their facilities up, at least abreast of the requirements.

So I look at this matter very seriously; but the question of remedy is not so easy. I had a thought this summer—and I wore out some shoe leather on it. It looked feasible for a time. I wanted to bring together a commission of gentlemen who were familiar with the Sanitary District law, and those engineers who were familiar with the history of the river and its requirements and with matters of navigation, who should sit with representatives of the City of Chicago, the United States Government, the State Board of Health and special organizations, and try and arrive at a conclusion as to what should be done with the Chicago river, in view of its uses for sanitation and as a harbor, and apportion, if you please, the due share of the work to the several agencies which are concerned—as the Sanitary District, the City of Chicago, the United States and possibly the State—and thus make of the Chicago river something worthy of the dignity of the port, of the great channel behind the city and a fit terminus for the waterway to the gulf. After a conclusion had been reached the State Legislature could be asked for whatever authority the Sanitary District might need. If the city needed legislation to do what devolved upon it in the way of bridges and tunnels, why, get that authority, and then turn loose on Congress and get what is proper from that source. Have all these agencies co-operate, which for years, ever since I can remember, if not playing at cross purposes, at least have not been

co-operating effectively. Something of this kind, in my judgment, must be done.

I believe this river should be 300 feet wide. Either that, or some equivalent of it, must be produced in Chicago. We have a sanitary canal which the law, as now construed, requires to be fed through the river. It has 6,000 feet of section in the finished earth cut. How can you feed that by a river 200 feet wide? The experience with the present *improvement* indicates a capacity of about 200,000 cubic feet only. Now a river 300 feet wide should provide a cross-section of 7,500 feet, or in that vicinity, or a reasonable surplus over the cross section of the sanitary canal so as to allow for vessels and other conditions of a harbor. Something of that kind should be produced. What it will cost or in what way the problem should be treated is not entirely clear, and requires careful consideration. This controlling work is spoken of. It would cost a considerable sum of money to build controlling works.

Mr. Keith—It is said it can be done for $200,000.

Mr. Cooley—No, it can't be. Five times that sum is more likely. Though I should not give an opinion, as I have not examined the matter. I would say that the cost of the controlling works spent in some other way would be better and contribute to an ultimate end. I think we are "up to" this question. In the next few years we must procure the legislation necessary.

Mr. Keith—If you will pardon the interruption, I would like to get after you; there is not a canal that empties from the lakes but has got controlling works.

Mr. Cooley—Where would you put them? Out at the mouth of the river at the lake?

Mr. Keith—No; put them in this end of the canal, up at Robey street. The Erie canal has controlling works; the Sault St. Marie canal has controlling works; the Welland canal has controlling works. Where a lake is subjeet to fluctuations of a foot or a foot and a half, or, like Lake Erie, sometimes three or four feet, what are you going to do?

Mr. Cooley—If you had a river of the proper capacity you would find it different, and your objections would cease.

Mr. Keith—We will never have the width you take—300 feet.

Mr. Cooley—By the time you get 200, you will have more requirements for water against the capacity of your stream than you have got today.

THIRD DISCUSSION.

Mr. L. O. Goddard—I can treat this subject only from the standpoint of one who has had some experience as an officer of a Chicago railroad company, and who has, in such capacity, made a study of the terminal facilities of railroads upon the Chicago river.

About six years ago the Chicago river had become so filled up that boats which came here from the Great Lakes to take grain out of Chicago, in seventy cases out of a hundred, found themselves grounded before they could get out of the river. It occurred not only to grainmen, but to all other interests upon the Chicago river, that something must be done, and that right speedily, to improve the conditions of the Chicago river so that Chicago could maintain its supremacy as a shipping point, or as the great commercial port of the Great Lakes. Therefore, the owners of property on the Chicago river formed themselves into an association, called the "Chicago River Improvement Association," consisting of the railroads, the large elevator interests, lumber, coal, and all the other large dock interests on the river. The object of that association was to get the city of Chicago to remove the obstructions in the river. Failing to get adequate relief from the city of Chicago, we went before Congress and the War Department, and succeeded in getting, in 1896, a large appropriation for dredging the river to the depth of 17 feet. The necessary amount of that appropriation was expended in a very short time by Major Marshall, representing the government here, in dredging the several branches of the river.

We also succeeded in getting an appropriation from Congress to cut off those projections into the river which made navigation exceedingly difficult. I think $175,000 was appropriated, and I think there is about $70,000 of that appropriation left.

The project depth of the river established by Congress in 1896 was only 17 feet, because of the depth of the tunnels. But in March, 1899, we prevailed upon Congress to amend the Sundry Civil Act, making the depth of the river the project depth, or real depth, of 21 feet; but it was on the condition that the city of Chicago should remove the center piers of the bridges and lower the tunnels, which were then, as now, almost insurmountable obstacles to navigation.

Since that time our efforts have been directed toward getting these obstructions removed. I will say very little about the tunnels, because it is believed by almost everybody in the city of Chicago that the Traction Company will lower them. But the Traction Company says it will not spend a million and a half dollars for low-

ering the tunnels until it can be assured of their use for twenty years, and also of the use of the streets for the same period.

So far as the removal of the obstruction caused by the center piers of the bridges is concerned, it was only a couple of years ago that we found definitely that the Drainage Trustees proposed to take possession of the river; and inasmuch as they have the power of levying taxes on the property of the district to make these improvements, we immediately got upon their necks and backs, so to speak, and insisted that they should spend the money as far as they could in deepening the river and removing the center piers of the bridges. They have already contracted to take out certain bridges and replace them with bascule bridges, and are perfectly willing to take out the balance as soon as they can raise the money by taxation or otherwise. The problem of raising money to carry on this work of taking out these bridges and replacing them with bascule bridges now confronts them.

On Friday afternoon they have invited different organizations from the city of Chicago to appear before them, by committees, to discuss ways and means of raising the money with which they can proceed to carry on this work. I take it that their main object is to have the citizens of Chicago express themselves directly as to what they would desire to have done, and particularly whether they would advocate the raising of the money by an additional ½ per cent tax on the assessed valuation of the property in the district, to afford the Sanitary District sufficient means to go on and do the work that they have in contemplation.

Severe criticisms have been made upon the extent of the projects which the trustees have in hand, and which they have voted to carry on, to wit: The widening of the river to 200 feet, which in round numbers, it is estimated, will cost a couple of million dollars; the deepening of the river finally to 30 feet; the substitution of bascule bridges with openings of 140 feet, and various other projects not quite so important—all looking toward a great ship canal. These criticisms and the fact that their funds are pretty nearly exhausted, have compelled the trustees to halt and ask the citizens of Chicago to indicate what course they should pursue. In other words, whether they shall take the flow of water which they have produced (and which Major Willard, in one of his reports, said was sufficient to comply with the statute, to wit, 360,000 cubic feet per minute) and let the work stop right there; or whether the citizens of Chicago are willing for them to go on and make a deeper water way, a wider water way, to satisfy the marine interests of the great lakes and the vessel owners who have built vessels 45 and 50 feet and upwards in width, and which draw from 19 to 22 feet of water.

Now, it occurs to me that the citizens of Chicago can be assisted

in this matter by such men as are in the Western Society of Engineers, if they will take this matter up, and, in their own way, advise and assist the citizens and advise the Drainage Trustees as to what they think ought to be done and what can be done.

So far as the shipping interests of Chicago are concerned, that business is leaving Chicago today because of the inadequate depth of water, and because vessels which have been in the habit of coming here to load and unload, refuse to come here now unless they are paid from 10 to 15 per cent more on the rates which are ordinarily charged. Rather than come here they will go to other ports, ports that are deep enough and broad enough in every way to receive these vessels. It is an emergency which must be met, and met very promptly, otherwise Chicago will lose her commercial supremacy. A very little cut in grain rates will take grain away from Chicago and the Chicago river, and send it even to the Calumet. It takes a very slight fraction of a cent a bushel to take grain away from Chicago and carry it to Duluth or Galveston. It costs the lumber men all the way from 10 to 15 per cent more to bring their lumber through the Chicago river to their docks than to the Calumet and other ports on Lake Michigan, for distribution throughout the West. This 10 to 15 per cent disadvantage is practically an extra tax on all shipments which ordinarily would come to Chicago. I know of one firm, at the beginning of 1900, which spent $50,000 in increasing its dock facilities in Milwaukee, and that firm now expects to bring its coal to other ports on Lake Michigan in vessels that will carry 7,000 tons. No vessel of 7,000 tons, as I am told, can get over these tunnels and wind around through the bridges.

As I said, it is a case of extreme emergency, and the Drainage Trustees and the River Improvement Association would be glad of any advice which a body of men like the Western Society of Engineers can give them.

Capt. J. A. Calbick—We are confronted with the contingency of the driving away of not only the large vessels from Chicago, but also of our medium-sized vessels. I, unfortunately, am interested in nine vessels, with other people, and control and manage those vessels which, ordinarily, are Chicago traders. They are owned here, and the other owners of the vessels outside of myself are lumbermen. While they would naturally like to have those vessels trade to their own docks, we find it better to charter smaller vessels and send our own vessels to other lake ports, simply because the conditions of the river are such that it is unsafe for even an ordinary sized vessel to navigate here. I never know, when a vessel starts from the mouth of the river, what is going to happen to her before she gets to her destination. The first thing I do, when

the vessel gets up to the other end, I call up the captain and ask him if he got through without damage. The conditions are such that we simply have to have tugs on our medium steamers. The tug bills on a steamer of 800,000 amount to a little over a shilling a thousand on lumber, and that shilling, in addition to the risk of damage to bridges, etc., will add another 10 or 12 cents a thousand on lumber. In that way, we find it much to our advantage to run our vessels to Cleveland, Duluth, Detroit, or any other port where we can get freight, and take it for less money than we could get at Chicago, for the simple reason that we consider the channel dangerous to navigate.

This year, on account of the excess of freights, there has been millions and millions of feet of lumber come here by rail that should have come by lake, for the simple reason that we do not see our way clear to carry it for the rate the railroads can.

Mr. Goddard—Allow me to ask the gentleman a question, as a matter of information, and a matter which, I presume, very few of you understand. I would like to ask how much it cost that vessel day before yesterday to get out of the river? I was told that it cost $1,000 to pull one vessel out of the river day before yesterday, as against, possibly, $200, the ordinary charge.

Captain Calbick—I could not state just what it cost in this particular instance, but from general knowledge I should say it cost six times as much as it should ordinarily. I had a very small vessel ground here last Saturday and Sunday, and it cost me $300 to lighter it, besides losing three days' time.

The Chair—Is it a fact that there is an arbitrary on vessel rates to Chicago at the present time? The captain can possibly answer that question. I was not aware that there was a charge made on the freight to Chicago as against other ports, for a like distance.

Captain Calbick—Usually, all freights to Chicago are about 25 cents a thousand more on lumber from Lake Superior points than to Tonawanda. I freighted lumber this fall to Tonawanda for $2.25, and at the same time I could have gotten $2.75 to Chicago. I freighted that lumber in preference to coming to Chicago, for 50 cents a thousand less to Tonawanda. With a large-sized lumber vessel in this current you do not know what the risk is, and before we take a cargo here, and take the chances of damage up the river, and delays with the tugs in the river, we will take a cargo to some other point a good deal cheaper, if it is obtainable.

Now, gentlemen, I don't want to be misunderstood, and I do not want you to think that I am a sorehead. I would rather see my vessels come to Chicago than to go anywhere else. I am a Chicago man and live here, and all my interests are here. But I am simply telling you the conditions as I understand them.

Mr. Goddard—Let me ask the Captain what difference it would make in your freight rates if the center piers of bridges were taken out and we had a straightaway course, even with the current of a mile and a half an hour?

Captain Calbick—Well, that is a pretty hard question to answer. It would certainly relieve the small-sized steamers of the necessity of a tug. We could navigate this current with our ordinary sized steamers, from the fact that there would be a surplus of depth of water; and if we had reasonably safe and sound docks and bascule bridges, we could navigate this river, after the men got used to it, without tugs, and, as I said before, that means a shilling a thousand on lumber and proportionately on coal. On lumber it is a tax of a shilling a thousand, and on our consorts it is the expense of furnishing an extra tug. We might not be able to tow them in with one tug, but we could certainly tow them out with one tug—though we can't do it now. Of course, on the smaller class of vessels it would not make so much difference.

Mr. Goddard—Captain, can you tell us the advantage of a turning basin at different points on the river?

Captain Calbick—It would certainly be of great advantage; turning basins in two places, in the south branch would relieve vessels from a great deal of tug bills and annoyance in getting into the upper slips to wind; some of them that can get up the river can't turn around. It would facilitate navigation in the river, it would be quicker and cheaper, and it would lessen the bills for damages.

Mr. Goddard—Captain, it is a general impression, I think, with most people that all of these vessels have keels.

Captain Calbick—That is erroneous.

Mr. Goddard—Will you explain what the bottom of a vessel looks like?

Captain Calbick—The bottom of most of the big freighters, as built today, is about as level as this floor here, perhaps, with the exception of a thickness of a steel plate where the keel ought to be. There is an extra heavy plate there, and that is about all the difference there is. In very exceptional cases they do rise, perhaps, three inches. Otherwise they are as flat as that floor. Of course, our wooden vessels (some of them) have a keel, but it is a very rare thing that it is over two or three inches below the bottom.

Mr. Goddard—When a vessel gets aground, it is the bilge that gets into the mud and not the keel?

Captain Calbick—With some of those vessels it is the whole bottom; in fact, those new steel ships, if they are aground they are all on the bottom, except a small portion of the bilge.

The Chair—The standard cross-section of a steel ship today has

three inches of dead rise, whether the beam be 36 feet or 50 feet, and the bilge has a radius of 3 to 5 feet.

Mr. Wilcox—Mr. Goddard was speaking for a river 30 feet deep. I would like to ask Mr. Powell what he thinks of building docks along the river for a 30 foot channel?

The Chair—The construction of a dock for a 30 foot channel would be a very serious problem. I have had occasion to build some docks recently where we were compelled to go down 28 feet below the surface and put in concrete foundations; in one case one wall of a building was built on top of the structure. My recollection is that the structure, which was both a retaining wall and a foundation wall, (and I got the benefit of the weight of the building, and therefore reduced the thickness of the wall to correspond to the added weight which the building gave) cost about $110 a foot to put in. That was on a 20 foot channel.

Taking that as a basis for figuring on thirty feet channel docks, we would expect the price to be very much greater. That would not matter greatly, if land was worth several dollars a square foot, as it is on the lower river, but where you get docks which are simply used for storage purpose for the handling of lumber, coal, etc., the price of land at the present time is not much greater in any case than a dollar per square foot. The price of a structure that would be adequate for the depth of 30 feet would probably equal the price of the land alongside of the dock. That would be the present condition for most of the district, i. e., all that which is used for storage purposes alone.

Mr. Artingstall—I know of two cases where they put in docks, one of which cost about $160 per foot and the other cost something over $200 a foot, if I remember. But there were improved buildings on them.

Mr. Noble—There is one point I would be glad to see developed a little farther. Lumber appears to be carried in middle class vessels, those running to Tonawanda drawing about 16 feet. Now, it has been stated that with the Chicago river improved, the tunnels lowered, and the bridge openings widened to 140 feet, those boats could navigate the river probably without a tug. If Chicago is going to be a first-rate harbor, it ought to be navigable, I presume, by the largest boats on the lakes, and I would like to ask whether, if the river were deepened to 20 feet and widened at the bridges to 140 feet, it would be navigable by the largest class of boats, the largest boats that would desire to bring coal into the harbor or take grain away from it, in such a way as to make this a competing point with other lake ports?

Captain Calbick—It certainly would; that is, with the winding basins and facilities for turning vessels around. There would be

nothing to hinder vessels of that size except the current. What we want to do, in order to make a competitive point here, is to make the river as much straighter, as much wider and as much deeper than some other rivers that have no current, in order to offset the current. Then you have it in a nutshell. And there is no reason why the river cannot be navigated with a mile and a half of current with the improvements spoken about when I went over the river with some of the drainage gentlemen. If they will carry out what they have mapped out and give the river a 21 foot channel, carry out all the improvements, get a 200 foot channel and make winding basins, it will be as good a harbor for any of the ships of any size that we have up to date as any of the harbors on the lake, except, perhaps, Duluth, or possibly Erie, or some of the places where it is practically a big open bay and where they have all the room they need. But it will certainly compare with Ashtabula, Cleveland and such ports—it would be away ahead of Cleveland and Buffalo.

Mr. Goddard—How would it compare with Milwaukee?

Captain Calbick—It would not be as good. Milwaukee has a big river; and another reason why it could not compare with Milwaukee is that you would have to navigate farther to do your business than you would in Milwaukee.

The Chair—Is there an arbitrary against Chicago in favor of the Calumet river?

Captain Calbick—There is an arbitrary on grain freight. I have chartered vessels myself to come from Milwaukee and load at Calumet at as high as ⅜ of a cent a bushel less, when freights were stiff here, in preference to going up the Chicago river. We also make a difference to Armour's north houses. I have made as high as ¼ of a cent there in some instances.

Mr. Goddard—I would say that ⅛ of a cent a bushel on grain from the west by railroad in favor of the Calumet, would take the grain to the Calumet in preference to Chicago.

Mr. E. Wilmann—As far as my connection with the harbor is concerned, there are two questions I have to deal with—they are the general public and the accommodation of the vessel owners.

Of course, there is no use in denying that the protections are a general offense to the vessel owners; they are in a bad shape and have been for a number of years. We are trying to straighten them up and get them into better shape. With our best efforts this year, spending quite a good sum of money, possibly more on the river than has ever been spent in one year for protection, I don't think there is a single place that I can find improved. No sooner has an improvement been made than a vessel comes and takes it out.

One very objective point is Canal street, and another at 22nd street. I don't know how many times we have driven piles to protect these bridges (50 foot piles, or as near that length as we can get them) and within a week they are gone. As an illustration: About a month ago, one vessel took away the protection at Canal street bridge and turned the pier around a foot and a half, knocking out the approach. We set a gang of men to work, pulled out the old piles, drove new ones, and tried to straighten the pier. While the men were working, another boat came along and took the new clump out, and twisted the pier 18 inches further. Now, it is impossible to do anything without considerable expense. It is a pretty hard proposition to make repairs under such conditions. At 22nd street bridge we had another lesson. We tried, to some extent, to police the river. That was in August. One boat going south took out the east approach to the bridge. I set a gang of men to repair it, and having repaired the damage the men were returning to the shop. Before they reached the shop we had to send a messenger after them to return, because another boat had taken out the other side. We had nearly repaired this side, when a third boat came along and took out the first one. We succeeded finally in getting away from there. Eight days later, another vessel came along and took out all the work we had done. Four separate repairs were required there inside of a month. That is pretty discouraging, but at the same time it is hard to keep away from it, and be criticised by the people that use the bridge as well as by the vessel owners.

The Chair—That is down in the vicinity of "Collision Bend?"

Mr. Wilmann—Yes. Another illustration: At the present time we are building a bridge over North Branch canal, at East Division street. As a consequence, there are now only two bridges in operation leading onto Goose Island. This summer, a boat going north took out 30 feet of the approach of the West Division street bridge, and knocked, practically, the whole protection out. Of course, the insurance companies became uneasy at once, because there was no access to the island except the one bridge. We put in a protection which we thought would resist anything coming up the river, in order to prevent any future accident of this kind. But now we have orders to pull out the piles driven at that time, because there is a large vessel that cannot get through. One vessel about the same size happened to get through while the protection was broken up. It is claimed now that we have to let the same sized vessels go through that have previously passed through the draw.

Of course, it is pretty difficult for a man to be absolutely right on any question, but on a general proposition, I think that we have

either to rebuild a lot of bridges at once, or we have to limit the size of vessels coming up the river, especially the North branch. The vessels that pass up the river now are of such size that they just pass between the abutment and the pier protection at this point, and any swinging of the vessel will cause damage to either the pier protection or the abutment.

The Chair—What is the limit on the North Branch?

Mr. Wilmann—There is no limit.

The Chair—And what is the limit of width, how wide a vessel can go up the North Branch?

Mr. Wilmann—We can accommodate a 43 foot vessel comparatively easy, but when they get to be 47 or 48 feet it means something must give way.

The Chair—Which usually means something besides the vessel?

Mr. Wilmann—Yes; it is usually something else.

The Chair—What width of vessel can go down the South Branch?

Mr. Wilmann—I do not know what size vessel can get through the Calumet Terminal draw. The stipulation was a 48 feet draw, but on account of the bend I do not think that a vessel with 48 feet beam could pass through this draw.

The Chair—A boat 350 feet in length can go through now. How many bridges will have to be removed before a boat 460 feet can go up the South Branch?

Mr. Wilmann—Well, I think they can go through up to Ashland avenue bridge. However, I am not positive as to that.

The Chair—Can they go up as far as the Stock Yards?

Mr. Wilmann—You don't mean the South Fork?

The Chair—The South Fork of the South Branch. That has been straightened; the Armour dock has been taken out and the river straightened at that point.

Mr. Wilmann—Well, I don't know. I suppose down to Ashland avenue. This is a bad point, almost as bad as any in the river.

The Chair—Can you answer that question, Mr. Wilcox? Can a boat longer than 350 feet go down the South Branch, the Stock Yards branch?

Mr. Wilcox—They can go to the Santa Fe elevators. They can't go up the South Fork, but they can go to the Santa Fe. They are in the West Fork. At present there is no occasion for boats of that size to go up the South Fork.

The Chair—Do you mean by the South Fork the Stock Yards Fork?

Mr. Wilcox—The South Fork is commonly called the Stock Yards Fork.

Mr. Goddard—In repairing the approaches of the bridges what length of pile do you use?

Mr. Wilmann—South of 22d street bridge you can't use piles longer than 35 feet; north of that we have, in places, driven piles 50 feet long.

Mr. Goddard—Isn't it a fact that the government requires in all the new docks built on South Branch a pile 40 feet long, and at least 15 inches at the top. I have been told so by dock owners.

Mr. Wilcox—The government specifications call for 40 foot piles and 28 foot sheeting, but on the South Branch shorter piling was used.

The Chair—There is no particular advantage in driving excessively long piles for a channel of 20 feet or 21 feet. I never yet have known a pile to shear at the surface of the ground; they break or belly out, due to the pressure at some point above this; neither does the pile give way at the bottom. All that is gained by using long piles is the size of the pile above the bottom of the channel. There are places south of Ashland avenue, for instance, on the south fork, where you can drive piles only 20 feet long, that is 20 feet below Chicago datum, on account of the hard pan or rock which underlies the river. Of course in that district a different kind of dock should be constructed.

Mr. B. J. Arnold—Mr. Powell, do you consider it practicable to drive piles in case you deepen the channel to 30 feet; that is, make pile docks with the hardpan so high as I understand it to be?

The Chair—Of course that would mean a different construction entirely. You could not use a sheet piled dock if you had a depth of only 20 feet to the hardpan. You must in any case drive your pile far enough to hold it in place. The pile is used under the most unfavorable conditions in a dock. It is used as a girder and not as a column; the pressures act at right angles to the line of the pile. It is used simply because it is cheap.

Mr. Arnold—The question in my mind would be if it would make a 30 foot channel pretty expensive.

The Chair—I believe the cost of a revetment for a 30 foot channel would be more than the value of much of the dock property that is used for the storage of freight along the river.

Captain Calbick—I will say, for your information, that I was at the meeting of the executive committee of the Lake Carriers' Association, in Cleveland, last week, and from what I could learn from our counsel, Mr. Goulder, and people well up in government matters, the Lake Carriers' Association expects that Congress will limit these lake channels to 21 feet. There certainly will be a limit, and I think the limit will be 21 feet, and when they get 21 feet, and have it from Duluth to Buffalo without a break, there is

not a gentleman of us in this room that will be in existence. They may get it, but there will always be spots that they won't have 21 feet. They have not a good 18 foot channel today, that is safe to navigate at an ordinary low stage of water.

Mr. Noble—Mr. Chairman, I think there has been a good deal of difficulty in making the 21 foot channel, in not properly determining the water surface of reference. At the mouth of the Detroit river the reference was intended, in the first place, to be mean stage, and it is probable there was some error made in determining it. It was also probable that the very act of correcting the channel lowered the water surface at that point and caused an insufficiency of depth.

It seems to me very probable that a limit will be fixed at 21 feet, as Captain Calbick has said. At a good many places in the lake, that is pretty near the natural limit. Across Lake St. Clair, for instance, the depth of water is only a little over 21 feet at a low stage. I think the datum plane of reference will be changed so that the channel will be 21 feet deep at what might be reasonably called the low stage of water, and steps are on foot now to carry that idea into effect.

The 30 foot channel, or any channel considerably more than 21 feet, entails a great deal of very difficult work. A 30 foot channel would mean an addition of several miles to the excavated channel at the foot of Lake Huron; it would also mean excavating a channel at the head of Lake Erie, pretty nearly out to the islands, and at a number of other points the cost would be very great, so that 21 feet seems to be the natural limit, as near as anything that can be named.

Mr. Goddard—Suppose the Niagara river be dammed, as they proposed at one time, what effect would it have upon the water over the Lime Kiln?

Mr. Noble—It is probable that the water of Lake Erie would be maintained at pretty near present high water, and it would operate to reduce the excavation required at the Lime Kiln crossing three or four feet. I think the project is quite feasible, and it would be the cheapest way of deepening the channel.

Mr. Goddard—How far would the effect be carried in the Detroit river?

Mr. Noble—It would be carried through the entire lower lake system, but not to anything like that extent. The raising of the surface of Lake Huron might be about a foot. There are no data at hand for determining this with precision, but that is as good a guess as can be made now.

The Chair—What is the hydraulic grade of the Detroit river?

Mr. Noble—I think the fall is a little over two feet from Lake

St. Clair to Lake Erie, and 5 or 6 feet from Lake Huron to Lake St. Clair.

The Chair—What is the current in the Detroit river at its most rapid point?

Captain Calbick—About a mile and a half current at Detroit.

The Chair—And what is it opposite Fort Gratiot?

Captain Calbick—At the northeast point about 3 ½ miles at Fort Gratiot, across to the Canada shore—of course, with a strong wind down Lake Huron it may reach four miles sometimes, but I think the average is 3 ¼ to 3 ½ miles.

The Chair—That has a channel 2,000 feet wide or thereabouts?

Captain Calbick—I think it is 2,300 and something.

CV.

THE SHOP AND LABORATORY IN RELATION TO ENGINEERING EDUCATION.

By Prof. Paul M. Chamberlain, M. W. S. E.

Read November 21, 1900.

Engineering education has received attention in this country in the last twenty-five years with accelerating interest.

Many people, and among them some illustrious educators, have come to think that it is possible to give that general training and education which distinguishes the cultured man, coincidently with the technical training required by the engineer.

The natural sciences gradually fought their way to recognition as requisites to a liberal education, and with them they brought the laboratory method which has some of the features of manual training as well as others. It is possible to imagine a book knowledge of chemistry, for instance, which could be acquired independently of the laboratory, but no one advocates such a course. The laboratory method has advantages, now so manifest that it no longer needs defense. Conspicuous among its advantages may be mentioned the following: It makes knowledge so gained by the student thoroughly his own; it trains the observational powers; it stimulates the desire to follow original investigation; it engenders the love of exact truth; and not the least valuable feature is the necessary dextrous manipulation co-ordinating the use of the hand with the perception of the mind. The direct application in later life of this dexterity in making analyses or compounding chemicals is used by only a small percentage of those who gain it, yet its value is generally admitted.

It is well, however, to observe that its value is quite dependent on the thoroughness of the training, as is the case with mathematics. Men whose training in arithmetic has been such that they are never quite sure of their results are not rare, unfortunately. They may have a good mathematical mind, and even be proficient in making application of the higher mathematics, but the fatal uncertainty of numerical calculations is ever present.

Manual training, as it is frequently taught, has for its aim the co-ordination of the hand and eye. It is a valuable training for everyone if it be taught by competent teachers, and it should be the special care of every member of this society who is interested in the education of children to see that competent teachers are employed in the public school system. Careless teaching in this, as in arith-

metic, is disastrous to habits of exactness, which are so desirable in all walks of life and especially so in engineering.

Manual training enters into what is classed in engineering schools as shop work, but it should not be confounded with it.

The engineer has need not only of the fundamental principles of science but also that intimate familiarity which keeps them ever present in mind when studying any problem new or old. It is the direct application of them which indeed entitles him to the name of engineer, and it is due to his powers of observation and application of the results of observation that he is able to accomplish satisfactory results. This faculty of observation is not created by laboratory and shop practice but unquestionably it is trained by them.

The question may be fairly asked, does it not depend largely on what special field of work the engineer is going to work in, as to the amount of training he should receive in such methods? The same question may be asked concerning mathematics, and yet there is a minimum amount deemed necessary to the equipment of the student. The instances where an engineer's opportunities are predetermined are few, and problems of engineering in any field are quite likely to hinge on knowledge and training of the shop and laboratory.

The shop training of an engineering student is a comparatively modern innovation, and has not yet won the universal respect accorded laboratory training. This lack of respect has been due mainly to two causes: first, incompetency of instructors; and, second, to the general misapprehension of what it should be expected to accomplish. Formerly the only way to prepare for mechanical engineering was by going through the journeyman's training, and the man who achieved success achieved it because of unusual ability and application. The method had many advantages, not the least of which was the eliminating of the poorer material. The difficulty was, however, that it eliminated much material that was still of a very good quality.

The age best suited to acquiring manual skill is about coincident with the age at which the mind is most receptive and retentive of mental training. The shop furnished good opportunity for the one, but meagre chance for the other. Then, too, as the modern systems of manufacturing came about, the apprentice was likely to be confined to one shop, if not even to one class of machines. The young man who was a good machinist, something of a pattern maker, a good tool dresser, something of a millwright, who could if occasion demanded set up a mould and had enough knowledge of drawing to put his ideas on paper, to say nothing of a knowledge of mathematics and natural sciences, was difficult to find. To meet the demand for such, classes were started in connection with man-

ufacturing establishments and shops in connection with schools. The former were conducted on a business basis and in the majority of cases fell through because they did not pay. The latter, being endowed, did not fall through and not being required to pay dividends did not progress as rapidly as they might have done. The selection of instructors was seemingly an easy matter; there were two classes to select from—one, men who had had experience in teaching; and the other, men who had had shop training, each sadly lacking in the proficiency posessed by the other. Shop foremen and superintendents who had brought shops up to a high excellence of work and efficiency, who might have been expected to make good shop teachers, were too high priced to put into such positions. It is worthy of note, however, that even with these drawbacks there were instances where great talent and genius were secured, and the students of such men occupy positions which testify to the teacher's ability and their inspiring influence. But in too many instances the training received brought contempt on the schools and failure to the students sent forth.

Demand is quite likely to induce a supply, and in the case of shop instructors it was no exception. It was found also that skilled mechanics could not be produced in the time available for a student to devote to the work, and cover also the ground in language, mathematics, drawing and science necessary.

The aim to make artisans has changed to the inducing of mechanical intelligence, if the phrase may be allowed. The aim, more thoroughly defined, may be gleaned from the catalogues of nearly any of the schools of technology, which is to give courses in woodwork, including pattern making; moulding and cupola work; forging and tempering; bench work and machine tool work. In wood work the student learns to plane, saw, chisel, turn, sharpen tools and work from drawings. In pattern work he not only is taught to turn out a pattern which is acceptable, but to bring to bear on it his best powers of adaptation in producing it with the least expenditure of his own time, at the same time keeping in mind the time of the moulder and the number of castings to be produced.

In the foundry he makes moulds in green sand, dry sand and core work, lines up, charges, and runs heats from the cupola, keeping records of pigs used, and mixtures, ratio of fuel to iron, percentage of good castings, etc. Problems in the production of special shapes are worked out by him as to whether they can best be done with patterns and green sand, part green sand and part core work, or by sweep work; whether three part flasks may not give way to two part flasks, etc. The mental imaging in such work is in nowise inferior to that required in descriptive geometry.

The forge work gives exercises in welding and forming iron and

mild steel; tool steel working, hardening and tempering; illustrations of the effect of differences in the composition of iron and steel upon their mechanical properties, and the method of treating the different cases; work in tool dressing, tempering in open fire, lead, sand bath, and oil.

In machine shop work there is chipping and filing, drilling, tapping and reaming, laying out work, turning, planing, shaping, milling and grinding, construction of reamers, taps, dies, and milling cutters, making special tools for rapid production of duplicate pieces on the turret lathe.

In connection with the work in the school shops it is customary to study special work in manufacturing establishments where they are accessible, not in a perfunctory way but with such analysis as is made possible by thoughts suggested by the instructor. The cost of production by one method is discussed in comparison with others; the time consumed by the journeyman in the production of a certain piece is inquired into, and the cost calculated accurately when data is obtainable.

Such training would seem to be of value in almost any work in life, to say nothing of the various branches of engineering.

The real question, however, is, can time thus spent be better applied to some other line of work? The actual time varies in different colleges from 425 hours to 1,629 hours, or approximately from two to seven months' full time.

Can any engineering course, mining, electrical, civil, mechanical, or even chemical, be considered well balanced without it?

In mechanical engineering it *must* be obtained in schools or in commercial shops, and in some branches very much more time should be devoted to it, but, in any event, the framework can be obtained in no commercial shop so economically in point of time.

The relation between drawing and shop work is very close, and the degree of practicability of the young designer's product is usually a very fair index of how much he has profited by shop work.

Another phase of laboratory work which has developed within a comparatively short time is what is frequently called engineering laboratory work. This differs from chemical and physical laboratory and shop work and yet combines somewhat of them all. It has for its object the examination of the strengths of materials and the various phenomena of durability, elasticity and peculiar fitness for which they are intended, the testing of various kinds of steam, gas and hot air engines, electric and water motors for power energy consumed and efficiency; the use and correctness of various forms of commercial instruments and appliances.

This class of work fixes principles of science and mechanics in a way not easily to be forgotten and gives practice in taking observa-

tions and writing reports which has direct bearing on a large and growing class of work which the engineer is called on to perform, either as a disinterested expert or as an employe of a corporation.

It differs from science laboratory work in that it deals with questions of engineering rather than questions of science as such. It makes application of science as a means to an end, and is concerned with the commercial side, typifying problems investigated with regard to their financial returns.

In pure science, and especially in mathematics, the tendency is to educate the student away from the conditions which we find, to those which are assumed or by great pains obtained. The tendency of shop and laboratory work is to keep him well within view of actual conditions which must be met and taken into account and frequently by approximations, but still within the range of admissible limits.

DISCUSSION.

Prof. C. V. Kerr—I am glad Prof. Chamberlain has brought up this subject. I would recall, in justification of that remark, the fact that most of our papers are strictly confined to the subject of engineering, and scarcely any of them deal with the subject of the education of the engineer. I would like to call the attention of the Society of Engineers, and especially the older ones, to this fact, that many of the gray-haired ones who are among us and who are now in charge of things will, in the course of events, turn those affairs over to the younger ones, and I believe they will realize that the work required of their successors will be more exacting even than the work which they have done; a higher standard of performance will be required of them, the opportunities will be greater, and consequently the training of the future engineer must be according to a higher standard than we have had in the past.

Recalling a bit of steam engineering history, Newcomen constructed, perhaps, the first real pumping engine, and he brought the duty of that pumping engine to, perhaps, 7,000,000 foot pounds per hundred pounds of coal. In two centuries we have attained to 20 times that performance. Newcomen did the best he could at that time, but Newcomen, with the training he had, would be simply a good blacksmith in these times—because he was a blacksmith pure and simple. I think that will make sufficiently clear my meaning in regard to the training which the engineer must have for the work of the future, and it is well that the engineers should have their attention called to, and their interest aroused in, these matters of education for engineering men.

A thought which Professor Chamberlain's paper aroused in my mind was that of a comparison as to the results of the education

that we get now, with the education in the old scholastic days, perhaps less than five centuries ago, when the best education they could give trained men chiefly for disputations. I have read somewhere that one of their topics was this, for instance: How many angels can stand on the point of a needle? Men were trained to use their faculties effectively in debate, guided, perhaps, by the logic of the Greeks, but we would not regard such discussion as useful nowadays, nor would we concede that it made a well-rounded, educated man.

And here I would advance this proposition, which I think will find favorable reception, that the engineering education as given now is the most educating education that is offered to young men, for the simple reason that it brings out the most of a man's faculties—which is education.

Another point which Professor Chamberlain alluded to is the increasing interest in engineering education, and I would like to add an illustration. A few days ago I was on South Canal street, in company with some young men who wanted to get acquainted with machinery, and we ran across, in one of the large machinery stores, a milling machine which is, perhaps, the highest embodiment of ingenuity in machine tool making—and you know, also, that such firms as Brown & Sharpe and the Cincinnati Milling Machine Company build what is considered a very high grade machine. That is the result of the evolution in machine building due to men who have grown up in the business. This milling machine, away back in the rear end of the store, was one of the finest pieces of mechanism that I have ever seen. The kinematics of the machine was of the highest order, and its mechanical finish was really artistic—not gaudy, but in good taste. This milling machine was put in the back end of the storeroom and the standard forms of machinery, representing the best practice, were put in the front end of the store. Why? Simply because that milling machine in the back end of the store was selling faster than they could be turned out by the men making it. One of these men is a technical graduate, the designer of the machine; the other is a skilled, but also an intelligent, mechanic. These two men are making a milling machine that is outselling the best milling machines in the market. You can draw your own conclusions. That is one effect of an engineering education.

Now, if I could take you to one of the largest power plants in Brooklyn I could give you another illustration. There is a 3,000 horse power engine driving direct connected dynamos, in which the guarantee for uniformity of rotation was so close as a quarter of one per cent. Now, those of you who have dealt with electrical machinery and know that the fluctuation in speed during a revolu-

tion of the old standard Corliss engine is such as to make some electrical work impossible, will realize what that means; and those of you who have studied the question of steam engine design will also realize the importance of this achievement. Now, the designer of that machine was also a technical graduate.

No such results had ever been attained by the old line builders, that is, those men who had simply grown up in the business and step by step had developed their machinery. It is simply an application of this rule that, other things being equal, the man who understands the scientific principles upon which he works will get to the front.

CVI.

RECENT PROGRESS IN SEWAGE PURIFICATION.

BY ARTHUR N. TALBOT, M. W. S. E.

Read December 5, 1900.

Systematic purification of sewage is of comparatively recent origin. England was the pioneer and, from the earlier chemical and irrigation projects, with their conception of great profits in commercial purification of sewage and their lofty ideals of restoring to land all the fertility of which nature had been robbed, down to the successful plants of the present day, has made much progress. Sewage purification in the United States has developed much more slowly. The classic report of Samuel M. Gray, on the disposal of the sewage of Providence, made in 1884, was one of the first public discussions in this country. The valuable investigations of the Massachusetts State Board of Health, from 1887 to the present time, not only have contributed to the world's knowledge of this important topic but have stimulated the sentiment and action of municipalities all over the country. Within the past four or five years several new processes of sewage purification have been developed or further investigated, and much knowledge of these processes and experience with their operation are now available. Without attempting to describe novel features or processes, and at the risk of repeating descriptions and results known to many members of the society, this paper will discuss in a general way, and without going into technical details and principles, some of the recent progress in sewage purification by discussing the various methods of sewage purification and the results obtained.

The principal methods of treating sewage may be included under the following heads: Dilution, chemical precipitation, irrigation, intermittent downward filtration, and the so-called biolytic processes. There are many variations and combinations of these processes; thus, dilution may follow chemical precipitation, and the biolytic processes may be preliminary to filtration or even to dilution. In discussing these methods the terms will be used as follows: Dilution involves the discharge of sewage into a body or current of water of such magnitude that the organic constituents of the sewage may be reduced to stable forms without giving offense or injury. In chemical precipitation, matter in suspension (both organic and inorganic) is precipitated as sludge in large tanks through the agency of chemicals and sedimentation. Irrigation implies the application of sewage to growing crops in limited

amounts. In intermittent downward filtration, sewage is applied in large doses intermittently to specially prepared areas of porous material. Biolytic processes include those where bacterial and other biological activities are especially prominent. While biolytic action forms a considerable part of other processes, such as dilution and intermittent downward filtration, it is more marked and rapid in those to which this name is given. Under the biolytic processes may be placed the septic tank, the coarse bacteria bed, the contact bed, and the continuous filter. These will be defined as they are discussed.

Sewage, the foul water carried through sewers, is very diverse in its composition, varying not only at different times of the day, but having widely different composition for different cities. Quality of water used, nature of manufactures and industries, fall and velocities in sewers, combination with or separation from storm water and street washings—all go to affect its composition. The amount of water used governs the strength of the sewage, and sewage of the ordinary American city is much more dilute than that of an English city. Sewage is not very foul—that of the average American city containing only 20 to 60 parts of foreign matter in 100,000 parts of water. The relative proportion of foreign matter in suspension and in solution also varies, and the character of the sewage in this respect has a bearing upon the system of purification to be adopted. Generally speaking, soft waters, industrial wastes, high velocities and falls tend to reduce the proportion of suspended matters and to increase the dissolved ingredients, while hard water, domestic sewage, and low gradients give higher proportions of suspended organic matter. This is especially noticeable with the sewage of some cities which are supplied with deep well water. Organic impurities form the principal part of the suspended matter, the average for several American cities being given as 71 per cent of the total matter in suspension; but in domestic sewage, having the suspended organic matter high as compared with the dissolved, the percentage of suspended organic matter may reach 80 per cent.

The strength of the sewage and the percentage of matters in suspension must be considered in comparing the various processes of purification, and particularly in judging of results of English experiments. It is desirable, also, to know the character of the organic matter in the sewage—whether it readily putrefies, or whether it contains a considerable amount of stable compounds. Generally speaking, the inorganic constituents are unobjectionable except as they may interfere with purification processes or require removal.

Before forming a judgment on the methods of sewage purifica-

tion, some attention must be paid to the purposes and ends of sewage treatment. The most common aim is to secure an effluent or mixture so low in organic matter, or having the organic matter in such stable form, that no nuisance, offense or injury may be given by the water to the lands adjoining the stream below the point of discharge. A more stringent requirement is that the water of the stream shall not be injured for the ordinary purposes of manufacturing by such discharges. A still more stringent requirement is that the water shall be free from organic impurities and shall contain no germs of disease; in fact, shall fulfill drinking water requirements. Local conditions will govern the rigidity of the requirements of purification, and obviously it will not be proper to exact drinking water standards in an effluent which is discharged into an impure stream, or where the stream is not used as a source of water supply. This question opens up a wide field, however, and many unsettled matters are shown whenever an attempt is made to fix a standard for a given locality. Yet it remains true that the process of purification to be chosen should be suited to the local requirements of purification. Where the dilution is not sufficient to receive the crude sewage, a partial or preliminary purification process may give an effluent which the stream will readily take care of. Where water is impounded for city water supply, land treatment is desirable. The degree of purification required is a local question.

Within the past few years, a considerable development in sewage purification has taken place. Experimental investigations have advanced our knowledge of several processes, and experience with plants of large capacity has tested theories. The experiments of the Massachusetts State Board of Health and their studies of the operation of intermittent downward filtration areas of several cities through a term of years; the thorough study of the greatest dilution project ever undertaken, that in the disposition of the sewage of Chicago; and the experimental work of several English cities, as well as of several places in the United States, with biolytic processes, together with other investigations and experiences, have marked an advance in sanitary engineering and put sewage purification on a much more rational basis. Much remains to be learned. The earlier studies were unscientific and not systematic. Much of the earlier work in England seems irrational and disappointing, and considerable expenditures of money there have practically been wasted or badly invested. This statement is not true of present conditions, and the projects and investigations are being made on a much more satisfactory basis. It will not be possible within the limits of this paper to do more than briefly recount what has been accomplished in recent years, and give some account of present tendencies.

Dilution.

Discharge into streams and bodies of water has been a common method of sewage disposal. It has long been known that where the conditions were favorable there is a considerable self-purification of sewage-polluted streams due to the biolytic action of vegetable and animal organisms, and the chemical action accompanying it and made possible by these conditions, but there has been little definite knowledge concerning the dilution necessary to prevent putrefaction and allow oxidation nor yet the requirements of time and distance to produce the desired results.

Chicago has made the largest experiment on sewage purification by dilution, and the complete results of the investigation are awaited with interest. The preliminary reports already made show a remarkable purification of the sewage-polluted water in passing down the stream—not merely a de-concentration due to dilution, but a reduction and oxidation of the organic matter. The chemical analyses show that this purification is marked, and it is even said that in spite of the increased quantity of sewage discharged into the Illinois river the total organic matter reaching the Mississippi is less than formerly. The biological studies show similar improvement, a marked decrease in the number of bacteria and especially in those species which are allied to the pathogenic bacteria. The final results will be of considerable scientific value. Of course it cannot be foretold what effect, either along pathogenic lines or in suspended organic matter, will follow the slow sedimentation of suspended matters and the entangled bacteria along the reaches of the river where the flow gives only occasional scour.

Sewage disposal by dilution must continue to be the method chosen by all cities situated so as to make this method available, and volume and purity of water in relation to the population, velocity and nature of current, and use and character of the stream below, will go to determine if such use is permissible.

Chemical Precipitation.

Chemical precipitation has its best example in this country at Worcester, Mass., where a plant treating an average flow of 17 million gallons of sewage per day is in operation—one of the largest and most successful chemical precipitation sewage purification works in the world. The methods of mixing lime and of handling the sludge have been much improved. The situation is peculiar—special manufacturing wastes, containing large amounts of iron, a stream already polluted, and opportunities for disposing of sludge. The results show removal of 52 per cent of the total organic matter (93 per cent of the suspended matter), but this

purification has not been considered sufficient and further treatment by filtration has been arranged for, and large filtration beds will be used for this purpose.

Many smaller chemical plants are in operation in the United States, but several of them are considered unsatisfactory and most of them are inefficient and expensive. A conspicuous example of the insufficiency of this process to fill the claims of its advocates is to be found at Madison, Wis., where the designers and contractors undertook to furnish an effluent from a combination of chemical precipitation tanks and rapid filtration beds as pure as the waters of the lake. Not only was there a failure to accomplish this purification, but the expense of operation was away above the guaranteed amount. A very hard water contributed to this result. The present administration of the city is studying the problem and trying to improve the conditions or attempt a new solution.

Chemical precipitation is only a partial purification, taking out about 90 per cent of the organic matter in suspension and probably averaging only 10 per cent of the organic matter in solution. Aside from expensive original construction and expensive operation both for chemicals and labor, its great drawback is the problem of sludge removal and disposal. As there is no reduction and no change in the impurities, their amount and the chemicals used result in a great bulk of sludge, which is very burdensome and a cause of great expense and annoyance. Besides, this process is wrong in principle; the chemical is a disinfectant tending to preserve the organic matter and postpone its decomposition, while the ideal process reduces the organic matter to inorganic forms or aids in transforming it into stable compounds. Recent developments have brought out processes which carry forward this transformation and lessen the sludge problem, while at the same time the expenses of operation are much less, and these results lead to the opinion that except for special conditions or exceptional sewage the chemical precipitation method is not to be recommended. London, England, is considering changing its immense precipitation tanks; Manchester is already planning to convert its precipitation tanks into septic tanks, and Leeds and other English cities will make the same change. It seems safe to say that in the light of recent developments the places where chemical disposal tanks are applicable are very rare, and it is probable that few plants of this kind will be built in the future.

Broad Irrigation.

Broad irrigation requires porous soil, low rainfall during crop season, and cheap land. Berlin and Paris are conspicuous examples in the use of this method. In both cities extensions of the

sewage farms have been made, and both report satisfactory results. In the western states of the United States, with low summer rainfall and on sandy soil, broad irrigation has proved to be a suitable method of sewage disposal. Instances have come to notice where the odor from the fields has been objectionable and a preliminary purification process has been arranged for. Even with porous soil the amount of moisture which vegetation will use is so small that very large areas are required, and this process is, therefore, of quite limited applicability. In sewage farms where the soil is heavy, the land may become "sewage sick." Generally speaking, at times the proper application of sewage to give satisfactory purification may sometimes injure the growing crops, and, conversely, care to secure best results for crop growth will result in inefficient sewage purification. As the financial side is likely to govern, the results from irrigation are likely to partake of practical rather than ideal considerations. It is now held that while broad irrigation may be applicable under special considerations, such conditions are rare.

Intermittent Downward Filtration.

Intermittent downward filtration continues to give satisfactory results. This process requires a very porous bed, like sand or gravel. Where such beds can be made from porous material *in situ*, the expense is not large; but where artificial beds are constructed with considerable haul of material the cost becomes very great. The studies of the experiment station of the Massachusetts State Board of Health gave an impetus to this process, and the experience of several towns in Massachusetts and elsewhere has borne out the conclusion given in these investigations. A high degree of purification has been effected. It may be said that 90 to 95 per cent of the organic matter may be removed—even 99 per cent under favorable conditions. The bacterial content is also largely reduced, 95 to 99 per cent being removed. This method is particularly applicable where the effluent is to be discharged into impounded water supplies. From 20,000 to 100,000 gallons per acre per day may be applied to beds of good material.

The permanency of intermittent downward filtration beds is generally taken for granted, though there is a silting up of the upper layer. Even though the surface is occasionally stirred, a layer must be accumulating which is different from the original sand, and this may eventually affect the efficiency and capacity of the beds, except for very slow filtration. In many plants some form of screening or roughing chamber acts to take out the heavier sludge, and where the sewage is pumped the receiving reservoir and the pumps aid in breaking up the particles more finely. While it is held that most of the reduction occurs in the upper 9 or 12

inches, the depth of 4 or 5 feet is generally considered desirable to insure high efficiency.

A difficulty attending the use of coarse filtering material in intermittent downward filtration is in the proper distribution of sewage over the surface of the bed. The principle of such beds implies the gradual sinking of the sewage into the bed, not saturating the bed (filling the voids), but spreading out in thin films over the surface of the grains and being held by capillary action throughout the bed, so that each layer of liquid is pushed downward by the next application of sewage, until finally, after several doses have been applied at the surface, the first of the effluent is forced out into the underdrains. This process permits contact with air and allows bacterial action, and the progress through the bed is slow, taking several days for the deeper beds. Yet the writer has seen beds which were expected to act as intermittent filtration beds, where the sewage was applied in such a way that it ran entirely through the bed in two or three minutes, while in spots the sand remained entirely dry. Even if conditions existed here for bacterial action, this rapid current would wash out the accumulated growths, and it is not to be wondered that the effluent from treatment of this sort showed very little change. The proper distribution of the sewage of intermittent filtration beds is a difficult problem, and one which should be treated with great care. With improper distribution the purifying effect may be very slight.

Biolytic Processes.

Before entering upon a discussion of the biolytic process, it may be well to consider the purposes of the different methods. In any rapid process, the first step involves the removal of the coarser matters in suspension in the sewage, and even of the finer suspended matters. The undissolved organic matter is very liable to putrefaction, and the removal of these solids also goes to prevent the choking of beds used in the later processes of purification. The work of removing and reducing the material in suspension may be called primary purification, and the process of reduction, hydrolysis.

The organic solids in suspension are but slowly and somewhat difficultly reduced. The organic matter in solution may be much more rapidly purified and will allow a different treatment. This part of the purification process may be divided into two portions, one called secondary, which is partly anærobic and partly aerobic; and the last, called the final, which is aerobic, and hence is nitrifying and oxidizing. The two are frequently grouped together in one step, somewhat to the disadvantage of the purification.

Two methods have recently been developed to carry out the primary treatment—the septic tank and the coarse bacteria bed.

Septic Tank.

A septic tank may be said to be a large tank, covered so as to exclude light and air, wholly or substantially, or if open, arranged so that the floating mat which forms on the surface will accomplish the same object, through which the sewage flows in such a way that it has a very regular current and a velocity so slow that the matters in suspension in the sewage rise or fall, by reason of difference in specific gravity, and are retained in the tank, where the organic matter will be decomposed, while the effluent flows out at the other end of the tank. Devices are used to cause the flow to be distributed over some considerable depth, to prevent surface currents, and to take the effluent from a depth free from suspended matter. Under the conditions of absence of sunlight and aeration and of moderate heat, minute organisms of the class known as anaerobic bacteria develop in great numbers in the tank. This biological growth and activity produces a chemical decomposition of the retained organic matter of the sewage—a reduction of its compounds into parts, a large portion passing off in the form of gases, a part as inorganic matter with the effluent, and a part as silt-like sludge or ash which is deposited in the tank. In many sewages a part is liquefied while yet in the organic state, and carried off in the effluent. Some effect may be found in the dissolved organic material. A light floating mat forms and covers the surface. The process results in the removal of a large part of the putrescible organic matter in suspension and its reduction into less troublesome forms.

The process is continuous and self-regulating, no attendance or labor being required except for the occasional removal of the sludge. The formation of gas is quite active, the gas passing through the floating mat and also sometimes escaping in great accumulation at clear points in the surface. It is easily ignited, and after stirring the tank a hot flame may be formed, rising 3 or 4 feet from the surface. An analysis of the gas made by Dr. A. W. Palmer, of the University of Illinois, is as follows: Carbonic acid gas (CO_2), 10.7 per cent total volume; free nitrogen (N_2), 27.8; marsh gas (CH_4), 55.3; ethane (C_2H_2), 6.2.

An effort has been made to utilize this gas for heating and lighting purposes, but it probably will not prove financially successful.

The sludge at the bottom of the tank is a black, muddy looking silt-like deposit. The average of two analyses of sludge from the tank at Champaign, Ill., gave: Water, 60.9 per cent; organic matter, 4.7 per cent; inorganic matter, 34.4. The floating matter at the top contains 92 per cent moisture, 3 per cent organic matter and 5 per cent inorganic matter. The sludge is of little value as a fertilizer.

The accumulation of sludge is relatively small, but as there is considerable inorganic matter suspended in the sewage, and as there must be some ash resulting from the reduction of the organic matter, an accumulation is inevitable. The amount of this is difficult to estimate, but it probably ranges from 3 to 6 cubic feet of dry matter per 1,000,000 gallons of sewage for the sewage of American cities. Much of this is from suspended mineral matter of the sewage. In plants where sludge has accumulated very slowly, the arrangement of the supply to the tank has been such that much of the suspended mineral matter was taken out before the sewage reached the tank. In many locations a preliminary shallow tank for retaining the heavier inorganic matter, arranged to be easily cleaned or flushed out, will reduce the septic tank sludge and will thus result in reducing the cost of removing sludge and also add to the efficiency of the tank.

The operation of the septic tank has been quite satisfactory. At Champaign the effluent has been sufficiently pure to permit its discharge into the creek, and no objectionable results have been noted in the water below. No odor is noticeable around the tank. A slight swamp-like odor is found in the effluent sewer. Inside the building the gases are very distinct, but the odors are not especially objectionable. When the contents are being pumped out, the smell is much stronger, but workmen suffer no great inconvenience. The odor from the sludge when pumped into the pit is more noticeable but has not proved objectionable. The tank at Exeter, England, which is really an experimental plant, continues to work satisfactorily, and the city is now constructing a large plant to treat the sewage from the whole city. The installations at Yeovil, Manchester and Leeds, all on experimental bases, show good results. These Cameron tanks are closed tanks, and sufficiently close that the inside air is under some pressure. In at least three places in England, open septic tanks have been used on a large scale—Manchester, Leeds and Accrington. In each case open chemical precipitation tanks were converted into septic tanks. A coating or mat soon formed over the surface, and the septic action was set up. At Manchester and Leeds, comparisons were made with the Cameron septic tank in operation at the same time, and the result shows almost no difference between the open and closed tanks. Manchester is planning to use open tanks in its new installation. Accrington has been using open septic tanks for two years, and is now treating 1,250,000 gallons per day by this process with satisfactory results.

The question of open or closed septic tanks is not wholly one of exclusion of light and air by the roof. The advocates of closed tanks claim that such exclusion is necessary to a proper septic action,

since the anærobic bacteria thrive under such conditions. However, sewage generally contains no dissolved oxygen. Even if the surface of the liquid were not protected from direct contact with the air by the floating mat on the surface, the opportunity for absorbing air while passing through the tank is very slight, and the evolution of gas acts to decrease the absorption of air. Light is fairly well excluded by the floating mat. Certainly, direct sunlight is excluded. It must be stated, too, that the cities using these open tanks are in a climate where the cloudy days are very numerous—particularly Manchester. It is evident that an absolutely tight and dark tank is not necessary. To my mind a matter of more importance than the complete exclusion of light and air is the maintenance of moderate and even temperatures in the septic tank. High temperatures seem to give strong putrefactive action accompanied by bad odors. Low temperatures reduce the bacterial and chemical activity. My observation indicates that 55° to 62° Fahr. give the best septic action, while temperatures above 65° and below 50° Fahr. are objectionable. Although the sewage will generally reach the tank between these temperatures, to protect the sewage from extreme temperatures will generally require a covered tank in such a climate as ours, though not necessarily a tight or dark tank, both by reason of the severely cold weather and the intense heat of summer. At Manchester in the coldest weather the temperature of the effluent of the open tanks is less than 2° colder than that of the closed tank, but in our climate the temperature sometimes falls 40° or 50° below the winter temperature to be found at Manchester.

So far as the writer has learned, no difficulty has been experienced with odors from the septic tanks in use. He was informed that the city of Worcester got objectionable results in experimenting with a chemical precipitation tank as a septic tank. Whether this was due to a peculiar sewage, or to other conditions, he has not been able to ascertain.

As a preliminary process, and as a partial purification, the septic tank is a promising method, particularly in dealing with domestic sewage. The success in Yeovil, Manchester, Leeds and Accrington, where strong manufacturing wastes are found in the sewage, would indicate that the method is applicable to mixed sewage. It will be of interest to see the outcome of the construction at Marshalltown, Iowa, where the septic tank is to be one feature of a system dealing with sewage containing large quantities of packing house wastes and wastes from a large glucose factory. The suggestion that it would be feasible to treat the wastes from the packing house district of Chicago in this manner may be worthy of consideration.

The first purpose of the septic tank is to retain and reduce the organic matter in suspension, but it seems to do more than this. The bacteria developed or the chemical compounds produced seem to put the sewage in better condition for further purification—at least for self-purification. At a time when the flow of water of the creek above the septic tank outlet, at Champaign, was a little less than the volume of the effluent of the tank discharged into it, chemical analyses showed a marked improvement in the water of the stream in a distance of 1½ miles; and while the dissolved oxygen of the creek water just above the tank outlet was at a little below the saturation limit, and just below the tank was at about half the saturation limit, samples taken at a point 1½ miles below show an amount of dissolved oxygen 50 per cent above the saturation limit. This rapid formation of oxygen is partly due to the presence in large quantities of the Uglena viridis, an organism which liberates oxygen in large quantities. The presence of an excess of oxygen is also a great stimulus to the chemical oxidation of the remaining organic matter.

The amount of purification effected by the septic tank depends upon the amount and condition of the suspended matters. Where these matters are not too finely divided it may be expected to take out 75 to 90 per cent of the suspended organic matter—an efficiency quite similar to chemical precipitation.

There is much diversity of practice in the size of septic tanks. English tanks have generally been constructed with a cubic capacity equal to 24 hours flow of sewage, though experiments there seem to show that there is little difference in results between tanks whose cubic capacity equaled 12, 24 and 48 hours flow of sewage. In the United States, with dilute sewage, septic tanks with cubic capacity equal to 2 to 4 hours flow of sewage have given good results. In discussing this question it seems to the writer that errors have been made in assuming (1) that the time required for passing through the tank is the same as that required to fill a tank of this capacity, or in other words that the flow is uniform through the depth of the tank, and (2) that the time of passing through the tank governs the efficiency of the purification. Concerning the first matter, observations by the writer in passing strong coloring matter through a tank having 5 feet of depth of water showed a time of passing through the tank equal to about one-third of that required to fill the tank, or, to put it another way, the effect is the same as for a velocity equal to the actual velocity and a depth equal to one-third the depth. If the mere mechanical action in the tank governed the desirable rate of flow it may be said that one hour's actual time in the tank with this very slow velocity would give a low enough velocity and a long enough time

to allow the suspended particles to subside. As the retained organic matter is held until decomposed, the time of flow through the tank has no bearing upon that. To my mind, the governing consideration is the space necessary to hold the floating or settled organic matter until it can be acted upon without being interfered with by organic matter retained subsequently. For a tank of too small size, newly arrived matter would cover matter not reduced, and hence crowd it back out of reach or otherwise interfere with the fermentation process. Besides this limitation, a tank of a size which will not require too frequent cleaning is desirable. For the sewage of most American cities where no storm water is admitted, considering its extreme dilution, it is probable that a cubic capacity equal to a flow of sewage for six to ten hours will give as good results as larger tanks.

Coarse Bacteria Bed.

The other means of primary treatment mentioned is the coarse bacteria tank or coarse Dibdin bed. It consists of a tank or bed filled with coarse irregular fragments of stone, coke, clinker, burnt clay or other durable material. The coarser solids of the sewage are screened out and disposed of, and the tank is slowly filled with the screened sewage, allowed to stand in the tank two to four hours, and then slowly discharged. A period of rest is then allowed, followed by the application of another dose of sewage, two to four applications being made in 24 hours. Enough beds are in use to allow proper alternation and rest. The change of flow is made by automatic devices or by attendants. In the operation of these beds bacteria soon develop around the pieces of coke or other filling material, the solids in suspension are retained and reduced by bacterial activity and some effect is had on the organic matter in solution. While there is opportunity for air reaching the bed between the time of emptying and filling, the action is mainly anaerobic in beds receiving crude sewage by reason of the large amount of organic matter in suspension left to be acted upon and the limited amount of oxygen available, though some nitrification takes place. Experience with coarse bacteria tanks seems to have shown the following difficulties :

1. Great care must be exercised in screening out paper, rags, and even the smaller matters in suspension ; and the disposal of this refuse is troublesome.

2. The fine suspended organic matters reaching the tanks, and the ash left from the reduction of the suspended organic matter, accumulate and decrease the capacity of the tank, and may even actually clog it.

3. The process does not have the best conditions for this primary stage—hydrolysis.

4. Too rapid emptying of the tank, or inefficient operation, may allow suspended matters to be carried on to the secondary filters, tending to clog them.

At Sutton, Surrey, England, where Dibdin beds have been treating the sewage of the town for four years, the coarse bacteria tanks have been filling up, and the town is now utilizing old chemical precipitation tanks as septic tanks for the primary treatment, carrying the effluent next through the coarse beds and then through the fine. This choking may be partially due to overtaxing, part of the beds having been worked up to a rate of nearly 3,000,000 gallons per acre per day. At Leeds, bacteria beds of mixed coarse and fine coke, treating 250,000 gallons per 24 hours, clogged in two years, and the beds were reconstructed with screened coarse coke; but I was told that the capacity of these beds is decreasing. The conclusion reached was, that in the conditions at Leeds, and with the material used, it was impracticable to deal with crude or with partially settled sewage, because the capacity of the roughing bed could not be maintained. Coarse beds in other places in England have hardly been in operation long enough to determine their permanency.

The consensus of opinion seems to be that there is little difference in efficiency in the various material for coarse beds—coke, broken slag, clinker, stone. It has been suggested that coke from old beds would be available for fuel, and also that broken slag and stone may, for shallow beds, be washed without great expense in handling, but the applicability of these proposals will depend upon local conditions.

The capacity of bacteria tanks depends upon the voids and volume of the beds, as well as upon the frequency of application. For material of fairly uniform size it may be considered that 25 per cent of the total volume of the bed will be available after the interior growths of slime are formed and some silting takes place. With beds 5 feet deep and three applications per day, this will give a capacity of 1,200,000 U. S. gallons per acre per day. It is probable that the more dilute American sewage may be applied for shorter intervals, thus increasing the quantity which a bed may take. The Local Government Board of England, for systems receiving storm water, requires a capacity sufficient to treat three times the normal dry-weather flow. For dry weather, then, the period of rest or the duration of application will be greater.

A third form of primary tank is sometimes used—a bed filled with coarse material through which the sewage flows upward con-

tinuously, an occasional resting spell being allowed. Its action is more like the septic tank than the coarse Dibdin bed.

Final Purification.

The secondary and tertiary stages of purification will be considered together, since there is no distinct boundary line between the two processes, and the treatment of the sewage beyond the primary stage is frequently combined in one operation. The preliminary treatment should have removed nearly all the suspended matter, and the remaining work is on the dissolved organic matter. The principal processes of final purification may be classed as (a) intermittent downward filters; (b) contact beds; (c) continuous filters. All of these processes are biolytic, in that the chemical and other changes carried on are largely due to the agency of bacteria.

Intermittent downward filtration has been mentioned, and is an efficient process. The area required is large, of course, as compared with the other methods.

Contact Beds.

Contact beds are beds formed of coke, screened gravel, finely broken slag or stone, etc. The bed is slowly filled with sewage, then allowed to remain in contact with the grains of the bed and the bacterial growth surrounding them for a certain period, say two hours, and then allowed to drain out slowly, after which a period of rest for the bed is allowed. The beds differ from the coarse bacterial beds already described, in the fineness of the material and the aerobic character of the biolytic action, the latter being possible in the absence of suspended organic matter and the presence of air. The terms fine-grained Dibdin bed, fine bacteria tank, rapid filtration, are also in use. The characteristics are intermittent contact, sewage free from suspended matter, and no dependence upon surface straining action. When the effluent from one bed is applied to a second bed, "double contact beds" are formed. As in coarse bacteria tanks, the intermittence may be governed by attendants or by means of automatic contrivances. Considerable variety exists in the arrangements for these. The distribution is generally made on the surface, a channel or system of channels being used. The dep'h of the bed is not essential, the volume governing, although the shallower depths allow freer access of air and require less head or fall. The usual depth is 4 to 6 feet, though good authorities prefer 3 feet, if the increased area is not objectionable, or, if feasible, two successive applications, double contact; in which case each bed may be as shallow as 2 feet.

The rate of application is comparatively rapid. With a depth of 4 feet, available voids amounting to 33 ⅓ per cent of the total volume of the tank, and four applications in 24 hours, the single contact beds will take 1,500,000 U. S. gallons per day. The second contact may be shorter, the cycle may be reduced to 4 hours, making 2,000,000 gallons per 24 hours for the second contact. These are extreme charges. The more usual arrangement is to apply not more than three doses per day for the first contact beds, a cycle of eight hours, and four or six doses for the second contact. For storm water purification beyond the first rush of filthy washings, where special beds are used for this purpose, the full cycle for the contact beds may be made as short as two hours. For this use the beds should be quite shallow. For systems receiving storm water and house sewage, the regulations of the Local Government Board of England provide that the regular contact beds shall be able to treat a volume of mixed sewage and storm water equal to three times the daily dry-weather flow of sewage before passing the excess to the special filters. Opinions seem to agree that there is little difference of efficiency in the various filling materials, though it is possible that porous materials have some advantages. On the question of the fineness of the material, it must be borne in mind that this fine material is much coarser than we have been accustomed to call fine grains for filtering beds—ranging, perhaps, from ¼ to 1 inch, though ⅛ inch is sometimes specified as the lower limit. For sewage which has been freed from matter in suspension it will be seen that the action of the contact beds is in no sense a screening or mechanical action.

A single contact removes from septic effluent or settled sewage about 60 to 65 per cent of the organic matter as shown by the albuminoid ammonia, and a second contact removes 50 to 60 per cent of the remaining organic matter, making an efficiency of 90 to 95 per cent for the whole process from the crude sewage. The second contact is almost wholly oxidizing and nitrifying in its action.

The real difficulty with contact beds is to maintain capacity. To obviate lost capacity, it is necessary to construct the beds of material which will not break up, and to thoroughly take out suspended matters before the sewage is applied to the contact beds. Some plan of occasional washing out the undigested matters with the effluent may be devised, and removing these by further subsidence.

Continuous Filters.

Continuous filters have the sewage applied by some device which sprinkles the sewage in drops, like heavy rain, over the surface of

the bed so that the surface is continuously damp. It differs from intermittent downward filters and contact beds, in that neither the whole bed nor the surface layer is ever saturated with sewage, the liquid passing in drops or thin streams through the bed while air is allowed to circulate freely through the interstices. Of course, individual filters are allowed to rest occasionally. The beds are usually made of coke, the pieces varying in smallest dimensions from two to four inches, and the resulting interstices between the material are correspondingly large. One device used in applying the sewage is the Candy distributor, a horizontal pipe which is rotated on an axis at the middle by the reaction of the discharging sewage, which is forced out from a series of small perforations at the back of the pipe under a head of 3 or 4 feet. Tippers, which are troughs which tip and discharge their contents when the center of gravity falls outside the support, and rows of projecting nails, are used as distributors.

Continuous filters, known as Whitaker beds, have been in use at Accrington, England, for two years. They are now treating 1,250,000 gallons daily of a sewage which is very concentrated, house slops being largely used for flushing closets. The sewage is first passed through open septic tanks. The exhaust steam of the pulsometer, used in lifting the sewage, is utilized in raising the temperature of the sewage. The beds are 10 feet deep and are open at the bottom and sides to allow the admission of air. Sewage is applied at the rate of 2,000,000 gallons per acre per day. The The effluent contains some finely divided suspended matter, mostly inorganic, the organic matter being quite stable. This is settled in a shallow reservoir, the resulting silt-like material being occasionally pumped back into the septic tanks. The beds seem to be free from accumulations of sludge, though when sewage is discharged rapidly at one spot on the bed, these black particles are washed out in larger quantities, and it is believed that the filters may easily be cleaned by such washing. At Accrington the results are considered satisfactory and the plant was enlarged the past summer. The results show a purification of about 83 per cent on the septic effluent and 92 per cent on the crude sewage. The effluent is used for boiler feed water. The Whitaker process is said to give higher nitrification than do contact beds, and the effluent is certainly high in nitrates.

At Leeds, triple continuous filtration is being experimented with, and it is understood that a process operating on this principle will be adopted by the city, the sewage being first passed through a septic tank. The separate beds are shallow, the total depth being only 10 or 12 feet. It is claimed that the combination of these

applications will give better opportunities for aeration and oxidation than the same total depth of flow through a single bed.

Miscellaneous Processes.

Various processes which differ from the contact beds and continuous filters are being tried—beds with layers of porous material for introducing air and separating the bacterial action into distinct processes in the passage of the sewage down through the filter beds, with air supplied under pressure, and with arrangements for supplying heated air, multiple trays of filtering material each with its own peculiar brand of bacteria, etc. These are generally complicated and expensive, both for construction and operation, and it is probable that generally they have no practical advantages over the simpler processes.

Similarly in the United States, a number of varieties of sewage purification processes have been introduced—filtration downward against an upward current of air, forced aeration of coarse bacteria beds during the period of rest, aeration by falling jets, etc. Some of these give efficient purification, but they are generally applicable only on a small scale and frequently the cost of construction and operation is such as to prohibit their use. In general, it is felt that the simpler processes will prove more satisfactory for general use. It must be said that the English Boards have usually required a final land treatment after the sewage has passed the newer processes described. This requirement may be attributed in part to the natural conservatism of the people and in part to a hesitancy in a country where the city population is so great, to letting go the advantage now held of requiring every precaution to be taken against further pollution of the streams.

In this discussion nothing has been said of the effect of these processes on pathogenic bacteria, and in fact little is known. It is known that high bacterial activity is detrimental to the development of pathogenic bacteria, and it seems probable that their numbers are very much decreased by these processes. The typhoid bacillus has been found to diminish rapidly in a septic tank, and single contact beds remove 90 per cent of them. It is held that these processes are detrimental to the survival of such organisms, but it must be concluded that the greater the aeration and the nitrification, the greater the probability of their destruction. For water supply from sources likely to be contaminated the only safe course is through the systematic filtration of the supply.

It is true that much of what has been said is based upon English practice and English investigation. The investigations of the Massachusetts State Board of Health have quite thoroughly treated American conditions of sewage for the chemical and intermittent

downward filtration processes, and as Massachusetts seems to be satisfied with these processes it is to be hoped that some State whose topography and soil are not altogether favorable to sand filtration, will make a thorough investigation of the rapid processes for the conditions of the dilute sewage of American cities. A dilute sewage is much more easily handled than a strong sewage.

Further investigation may change practice, but so far as recent developments indicate, the value and applicability of the various processes may be summed up as follows, subject, of course, to ever-governing local conditions and requirements:

1. Dilution is acceptable whenever the volume of flow, velocity of current, purity of the water, amount and nature of the sewage and facilities for self-purification will result in conditions in the streams below which will not give offense or injury to riparian owners or users of the stream below—conditions which cannot be stated categorically.

2. Chemical treatment and broad irrigation are applicable only for special and peculiar locations and conditions.

3. Intermittent downward filtration is advantageous where sandy areas, which can be cheaply transformed into filter beds, are available, and especially where drinking water standards are a necessity.

4. The septic tank has an advantage over coarse bacteria beds for the roughing or primary process in that it is more suitable to the hydrolytic action for reducing suspended organic matter, and may be more readily cleaned. The septic tank mixes and equalizes the sewage. Whether the effluent requires further treatment depends upon the purity required.

5. As rapid processes, both contact beds and continuous filters give good results, and the choice will be made on the basis of cost, applicability to the engineering requirements of the location, and ease of cleaning out accumulations of silt.

6. For stringent requirements of purity of effluent, a final land treatment may be necessary.

DISCUSSION.

Mr. W. S. Shields—Professor Talbot has given a very clear description of the methods of sewage purification as practiced at the present time, especially so in bacterial processes, and as he designed and built the septic tank at Champaign, Ill., which has been so successful in its operation, any statements made by the Professor will be considered good authority among sanitary engineers.

The plant at Champaign has made the city a Mecca for sewer

committees from all over the United States and Canada, who invariably return with their traveling flasks filled with the effluent from the plant, and a firm conviction that the question of sewage purification has been successfully solved; and as a consequence, it is very difficult to get these committees to recommend any further treatment than the septic tank.

It is to be regretted that no complete bacterial plant of any proportions has been constructed and successfully operated in the West. The one at Independence, Mo., designed by Mr. Rosewater, of Omaha, is the largest; but even this one lacks sufficient test, on account of so few sewer connections having been made with the system.

We have had some experience with a small plant consisting of a septic tank followed by single contact beds, then with intermittent filtration to the sand beds, and from a study of the English practice, I believe that excellent results can be obtained from plants constructed on these principles. The septic tank, followed by double contact beds, promises to give the best results. Our experience with operating these beds as bacteria or coarse grained filters, proves that the surface of the beds clogs very quickly, and that bacteria beds cannot be expected to prove successful without the aid of a septic tank or some other process which will break down or remove the particles in suspension. The best manner of arranging and operating these beds must be worked out by actual experience.

The character and condition of the sewage as it reaches the plant must be considered in determining the size and form of the septic tank. The action of these tanks being anaerobic, while the first action in the sewers as the sewage leaves the houses and mingles with the water in the sewers, which contains a large amount of oxygen, must necessarily be aerobic, and the final action in the contact beds being aerobic, it is, therefore, necessary to provide the best conditions for the changing, first, from aerobic to anaerobic, then back to aerobic, after leaving the tank. The sewage should, therefore, be brought to the tank quietly and under low velocities, without any fall—long, deep sewers being preferable while in leaving the tank the sewage should be agitated and exposed to the air as much as possible. It appears from the reports from the English plants that it requires a first contact bed to overcome the anaerobic conditions, and if some means can be devised for doing this previous to its entering the primary beds, much better results may be expected.

The Professor refers to the amount of oxygen absorbed by the effluent from the Champaign tank when flowing in an open stream. We have noted similar results, and are now constructing a tank

arranged in two long, parallel compartments, the sewage to pass through one with a submerged current for septic action, and return through the other with a forced surface flow, thence over a wide, flat-bottomed channel in a thin layer to the controlling chamber, where it enters in rotation the different primary contact beds.

The important features of the contact bed process are the changing from aerobic to anaerobic conditions, the size, depth and character of filling in the contact beds, and the selection of automatic devices for the filling and emptying of the beds. The filling device should be adjustable to an extent that the beds may be filled quickly, stand full for a period of time which may by test prove best for each plant, and then to drain slowly and quietly on to the secondary beds or into the outlet drain. The designing of such device and its application to the different conditions which must be met in each plant, makes it very difficult to get any appliance that will operate in all cases. The principle which promises to give the best results, however, so far as I have been able to study the question of controlling devices, is that of the slot machine, in which a moving weight or ball will pass from the controlling valves of the different tanks in rotation, its weight opening the valves and itself being lifted back and delivered to the next bed by a float which is raised by the filling of the tank. This device is so flexible in its nature that beds a long distance apart may be readily operated, and any number can be grouped together, operated singly or in pairs. Provisions can be made for the cutting out of the beds for rest and repairs.

I am pleased to note the distinction which Mr. Talbot has made between bacteria beds and contact beds, and should have been better pleased if the term "septic" might have been dropped and another substituted for the tanks, as the tanks in this country are enough unlike the English septic tank, as patented by the English engineers, to bear a different name.

Mr. O. Guthrie. The early efforts of Chicago toward sewage precipitation were begun with the old pumping works of the I. and M. canal. These were constructed and put in operation in 1848 and designed to supply water for the summit level when the natural feeders failed. In 1860 these works were reconstructed and materially enlarged and improved in anticipation of a probable necessity of pumping Chicago sewage. In the new works there were two lift wheels, 38 feet in diameter, 10 foot face and dipping in the river 5 feet below datum. These wheels were capable of being operated anywhere in the range from one to four revolutions per minute, and lifting, approximately, 5,000 cubic feet of water per revolution, 10 feet high. One wheel, crowded to its limit, was fully equal to the capacity of the canal.

From 1860 to 1868, both included, these works were operated under my supervision, much of the time at the expense of the city, for pumping sewage.

In 1868, when Chicago had a population of 252,000, the pumping works were operated continuously night and day for about six months, with the natural feeders shut off, in order to draw the largest possible quantity of water from the lake. While no careful measurements were made of the water pumped during this period, it is approximately close to say that an average of fully 3½ revolutions per minute of one wheel were made, and an average of 15,000 cubic feet of water actually delivered into the canal above the lockage and leakage; or sufficient to change the water in the river once in 24 hours. It will be borne in mind that the temperature was favorable for decomposition. The odor from the water at the pumping works was quite offensive; the water had become quite dark-colored, would change white paint to lead color in a few hours and all the copper pipes about the works looked as though they had been heated. There was no sickness among the employes, but I had two attacks of diphtheria, one in 1868 and the other a year or two earlier. The sludge this year began to precipitate quite freely in the canal at Bridgeport and at the Lockport basin to such an extent as to interfere, somewhat, with navigation, but this deposit was charged by the canal authorities to the Ogden-Wentworth ditch. In my opinion, however, it was sludge.

During the pendency of the Chicago drainage bill, Joliet sent a delegation, headed by the mayor, to Springfield to oppose the measure. This delegation denied in the most emphatic manner, both as individuals and as a body, that Joliet had ever experienced any unpleasant effect, either from odor or otherwise, from Chicago sewage before the opening of the deepened canal in July, 1871. Upon this point I am unable to testify, but in my opinion they were not fully justified in their statement. On Monday, November 26, of this year, when the temperature had, for several days previous, been close to the freezing point, I visited the controlling works at Lockport; at which time 225,000 feet of water per minute was passing, and which had probably been about the average. I readily recognized a much attenuated but very familiar odor, which doubtless would disappear very soon after the passage of the water over the dam and succeeding rapids.

Professor Turneaure—I came here tonight to get some information, and I think I have got a good deal from Professor Talbot.

I come from that unfortunate place, already referred to, where they have a sewage plant on their hands which is something of a white elephant. It may be of interest to those present to know

that the plant will be abandoned on January 1. What we will do now is a question.

The plant has been pretty fairly described in engineering papers. It consists briefly of a chemical disposal tank, using lime as a precipitant, and an area of about ⅛ of an acre of filter beds, consisting of polarite and sand. The amount of sewage varies from about 350,000 gallons in dry weather to about 1,000,000 gallons in wet weather. As a matter of fact, we have been unable to get more than about 300,000 gallons through the filter bed, with the head that we have available, so that the work has been essentially chemical precipitation. As a chemical plant, I think the results are about as satisfactory as are usually obtained from such plants, with the exception, perhaps, that we have a great amount of sludge. The water is very hard, and using lime as a precipitant we get so much sludge that for a time it was necessary to run the sludge press night and day. We have since been able to reduce the amount of sludge considerably by using less lime, and get about as good results as before.

As was said by Professor Talbot, the sanitary company that put in the plant made some very high guarantees as to the purity of the effluent and the expense of operation. In all respects they have come very far below the guarantee, and the city will probably endeavor to recover some of the money it has paid for the plant. The expense of operation is probably the worst feature of the plant. It cost in the neighborhood of $7,000 last year to operate it, in addition to the cost of pumping, which, of course, was quite an item.

I would like to inquire from Professor Talbot to what extent he found the English plants removing the sludge from the septic tank, and what method was employed in removing the sludge? I have kept very close watch of the papers, and the last information I had in regard to the separate plant was that they had not removed any sludge at all. I wondered if that was possible.

Prof. Talbot—Little definite information on the amount of sludge accumulating could be obtained, and the conditions of operation are not wholly representative. The experimental tank at Exeter receives its supply of sewage from a main sewer after it has passed through a large sand catcher which removes much of the heavier inorganic matter, and the tank gets sewage with comparatively little mineral matter in suspension, and therefore is not representative sewage. The sand catcher is cleaned frequently. A large amount of sludge has accumulated in the septic tank, but as its capacity is so great it has not yet been cleaned. In the plant under construction, provision is made for removal by pipes. At Accrington the sludge is removed by the channels which were

constructed for the chemical disposal tanks now used as septic tanks, and the sludge is run on waste land. The amount is materially less than when chemicals were used, and the sludge does not have the offensiveness of the old sludge. It may be said here that the saving in chemicals alone in the treatment of 1 ¼ million gallons of sewage per day amounts to £1,500 a year. At Leeds the method used with the chemical treatment is followed—passage through a conduit to a well, pumping into lagoons, draining and drying and carting away. It was calculated that the sludge amounts to about 30 per cent of the total matter in suspension in the sewage, which of course is heavy with manufacturers' waste. Including the large amount of chemicals used in the precipitation process, the amount of sludge is probably one-fourth to one-fifth of the chemical process sludge. At Manchester the sludge from the precipitation tanks is pumped to a sludge reservoir, run into a sludge boat, and carried to sea, and that from the septic tanks will receive the same treatment.

CVII.

THE ROBERT A. WALLER MUNICIPAL LIGHTING PLANT.

By Edward B. Ellicott, M. W. S. E.

Read December 5, 1900.

What I am intending to say to you will not be of any value from a scientific standpoint, but should be of interest, as it is a description of an electric lighting station in which each one of you is part owner. The Robert A. Waller municipal lighting plant was named in the memory of the late Comptroller Waller, who aided the extension of the lighting system in every way possible. It is doubtful if in the history of municipal affairs a man could be found who actually accomplished as much as Mr. Waller did in the term of his office, which, unfortunately, was far too short. He was always ready to aid the head of a department in carrying out any work that was for the benefit of the public, and it was largely due to his persistent efforts that the Department of Electricity was given an opportunity to install the lighting station which now bears his name. Work was first commenced on the station in the spring of 1899, but later abandoned for several weeks pending a change of plans for lighting the city.

In constructing this station the first intention was to build a model lighting station regardless of the first cost. Proposals were received for about everything that should be installed in a model plant and would in any way increase its efficiency. The total amount required for the station on a basis of 1,000 lights would have been $89,000. The plans were then changed, and the station, as it now stands, cost the city about $60,000. The building is 43 feet wide, 187 feet long and 20 feet clear of trusses in engine and boiler room. The front of the building is constructed of Milwaukee pressed brick and neatly trimmed with white sandstone. The engine room is lined with pressed brick, which imparts a neat finish, easily kept clean, and is of a substantial character. The floor is of cement and concrete the only wood used in the construction of the building is in the doors and window frames making the building thoroughly fire-proof. Steel trusses are used for supporting the roof, which is composed of book-tiling laid with cemented joints. An octagonal brick stack, 96 inches in diameter and 175 feet high, is located at the rear of the building.

The boiler room equipment consists of three water tube boilers, each with a capacity of evaporating 12,000 pounds of water per hour. Two of these boilers are provided with the McKenzie auto-

matic traveling grates. These are the first grates of this make that have been put in service and their operation may be of interest.

The boilers are supported without any attachment to the traveling grates or their frames. The grates are mounted on a self-contained frame, which is easily and quickly rolled out from underneath the boiler, to enable repairs to be made either to the grates or the furnace walls. The grates consist of slotted iron sections mounted on sprocket chains and operated in the usual manner, the coal being fed in the grates at the front of the boiler, and the ashes or cinders carried over the end of grates at the rear of the furnace. The speed of the grates is varied by means of a differential ratchet and the coal feed is varied by a gate extending the full width of the grates.

Back of the grates the gases enter a combustion chamber where a part of the gas, not consumed in the firebox, is ignited. The indications are that the average saving with the mechanical furnace over a hand fired furnace is fully 15 per cent. This saving cannot be effected, however, if an attempt is made to force the boiler above its rated evaporating capacity.

These furnaces were originally installed for the purpose of preventing smoke, which was objectionable in the section of the city in which the plant is located. The results obtained have been highly satisfactory, and the only time a particle of smoke is discernible is when the fire is first built under the boiler. After the brick work becomes heated and a good bed of coals obtained there is not the faintest sign of smoke.

Since the plant was started in January there has not been smoke enough produced to blacken the top of the stack, although at times the boiler has been evaporating 15 per cent more water than its rated capacity.

The engine room is equipped with 800 h. p. cross compound Elmes marine type of engine, speeded at 200 r. p. m., and an 800 h. p. cross arm Westinghouse special engine, speeded at 200 r. p. m., each connected to an end of a shaft that runs the full length of the engine room. Friction clutches are used at each engine, enabling either or both engines to be used.

One of the friction clutches is of the ordinary Hill six arm type, 100 horse power capacity, and the other, which has just been installed, is a magnetic clutch of the same capacity, manufactured by the Arnold Power Station Company.

Four General Electric 160 arc light machines are belted from the line shaft. Five more machines of the same type are installed in a manner that is original in this station. The five machines are coupled together in a line by means of a special insulating coup-

ling, and are operated from one drive, which consists of twenty turns of 1⅛ inch manila rope, the driving sheave being placed on the line shaft. This arrangement was decided upon in order that space might be saved, and with a further view of the application of power from the drainage canal. All of the station equipments for the past two years have been made with the idea that at no very distant time this power will be obtained by the city, and its adaptation to existing apparatus will therefore be comparatively simple.

These direct connected machines have been running about one month, and during that time have given the very best of results. While an accident to the shaft of the first machines in the series would cut out of service the balance of the machines, there is very little liability that such an accident will ever happen. A complete machine, or the armature of any one of the machines, can be removed and a blank piece of shafting put in its place to admit of running the other machines. This blank piece of shafting is kept at the station and can be put in place within half an hour. There is no accident that can happen to any one of the machines, except the breaking of the shaft, which can cause the series of machines to be shut down. Any one of the bearings might burn out without danger of the armature coming in contact with the pole pieces. The burning out of an armature on any one of the machines would not in any way affect any of the rest of the machines, nor would a grounding to the core of one machine affect any other machine, for the reason that they are thoroughly insulated from each other.

The labor account in this station has been reduced to a minimum. There are employed in this station two engineers, three firemen, one dynamo tender and one cleaner, the entire care and operation of the station being divided up among these men. With only a partial load of 760 lights the station labor cost is on a basis of 67 cents per light per month. This will be practically reduced one-half as soon as the balance of the lights are in service.

The station is designed for a capacity of 2,000 lights and the present equipment is for 1,200 lights. There are now in operation 760 lights and the cash cost per light per year is on a basis of $41.00, which will be substantially reduced when the balance of the lights are in service, for the reason that there will be practically no additional station expense, except the coal required.

No money has been spared to make this station one that can be depended upon to furnish good service and within reasonable economy. The actual station equipment consists of the best and most economical machinery that can be purchased within the means of the city, and when entirely completed will represent a station that you, as citizens of Chicago, will take pride in.

The tests obtained by the city on engines similar to those used in this station indicate that an operating economy of 16½ to 17 pounds per h. p. per hour will be secured. No tests have been made as yet, for the reason that a full load has not been connected to the engines.

One of the circumstances that renders it difficult for an engineer to secure the very best of results in the construction of a municipal plant is the requirement of the law that contracts must be awarded to the lowest bidder complying with the specifications, and, as you know from experience, one bid might be much better than another, both of which complied with the specifications, no matter how carefully drawn.

In the construction of the R. A. Waller station it happened that very desirable proposals were received, and the entire station will bear close inspection when entirely completed, and furnish to the southern section of the city a reliable and economical source of light. The lighting stations of the city are public institutions, and any one wishing to inspect them will find the doors open. No money has been expended in brass trimmings or tile floors, but you will find substantial, economical machinery, designed and installed for the purpose of furnishing good service at a reasonable cost.

DISCUSSION.

Mr. W. H. Finley—I would like to ask Mr. Ellicott if, in investigating the question of electric lighting, he investigated any other method of running the dynamos than that of steam power? For instance, a gas motor?

Mr. Ellicott—I have investigated the question of gas engines, and I am going to make a practical test within the next few weeks. There is a company that has built an engine it claims a great deal for. Frankly, I haven't very much faith in this engine. We have tried similar engines and never secured any satisfactory results. The fluctuation in the speed seemed to be such that first-class results could not be obtained. However, they claim to have overcome that, and I have seen the engine in operation. Our load being practically the same from the time we start until we shut down, it might apply very well to our class of work.

I saw, at Columbus, Ohio, early in the summer, a thousand horse power gas engine which was driving an alternating machine, but I could not get any figures as to the cost of operation. It was run by the gas company and they would not give me any information. But the engine worked perfectly, and without any change in load gave a very steady light. They had some difficulty in starting it up, and it requires a pretty good man to operate it. I think, how-

ever, it will eventually solve the question so that we can dispose of steam, and simplify matters a great deal. This engine I first spoke of was one of Mr. Elms' build. He has been working on this engine for the last six years, to my knowledge, and has only now struck it. They are going to turn it over to me to make some practical tests on it, to see whether it can be applied to electric lighting.

Mr. Stephens—I would like to ask if the price of $41.00 is the total cost?

Mr. Ellicott—Forty-one dollars is the total station cost—the cost of trimming the lamps and everything that enters into the production of the light, including the 5 per cent allowance on the total cost for depreciation. It includes every cost that enters into the furnishing of the light.

WILLIAM T. CASGRAIN.

Died September 28, 1900.

William T. Casgrain was born at Rivière Ouelle, Province of Quebec, April 5, 1835. He died in Chicago September 28, 1900. Mr. Casgrain was elected to active membership in the Western Society of Engineers February 7, 1888. He was the son of Hon. C. E. Casgrain, who was at one time commissioner of public works for the city of Quebec. Mr. Casgrain was educated at Sainte Anne's College, near his birthplace.

At 18 years of age he went to Quebec to pursue his studies in engineering, attaching himself to a civil engineer in that city. About two years later he was engaged as assistant engineer with the U. S. Engineer Corps, under General Meade, with headquarters in Detroit. Until 1866 he remained in that city, after which he was stationed at Milwaukee. Mr. Casgrain made the first survey of the Calumet river in 1869 and laid out the lines for the first work of constructing a harbor at South Chicago. He continued in the U. S. engineer service until 1880, and during that time was in charge of the lake surveys, his principal work being the surveying and superintending of the Sturgeon Bay canal; the contractor for the work being Mr. O. B. Green, of Chicago.

In 1880 Mr. Casgrain was appointed commissioner of public works for the city of Milwaukee, which position he filled, much to his credit, until 1882.

In 1882 he began his business career as contractor, and continued in business in Milwaukee until 1890, when he moved to Chicago, associating himself with the Kimball & Cobb Stone Company.

The prominent works for which Mr. Casgrain contracted were: U. S. Government breakwater at Ontonagon, Mich.; rebuilding of superstructures of breakwaters at Milwaukee, Wis., Racine, Wis., and Chicago, Ill.; harbor pier at Sheboygan, Wis., and rebuilding of substructure of the Milwaukee dam. Mr. Casgrain was also, in 1884, engaged on work on the Morrisburg canal, Morrisburg, Ontario, on the St. Lawrence river.

In 1894 and 1895 he secured a contract from the U. S. Government for the rebuilding of the levee along the Mississippi river, from Canton to Warsaw, Ill. The result of this work, while very satisfactory to the government, was disastrous to Mr. Casgrain, owing to excessive wet weather and floods. In the face of his impending ruin he, with his indomitable pluck, pushed the work to a conclusion. In 1899 and 1900 Mr. Casgrain was superintendent

for Jas. Stewart & Company, of St. Louis, for the building of the court house at Ft. Wayne, Ind., the contract for this structure being taken by them.

JOHN HENRY ESSON.

Died August 23, 1900.

John Henry Esson was born at Eden Mills, Ontario, November 9, 1862. He died in New York City, August 23, 1900. He was elected to associate membership in the Western Society of Engineers January 19, 1897.

Mr. Esson, before coming to the States, was interested with his father in the contracting business. The firm is said to have done a great deal of heavy work for the Michigan Central Railroad. After the death of his father, Mr. Esson branched out for himself, beginning his career under the late Ferd Hall on the Monon Railway. Mr. Esson constructed a considerable number of the streets in La Grange, Illinois, and several in Chicago. He was also connected with the work of elevating the tracks of the C., B. & Q. and the Pennsylvania Railroads.

He was a man who had many firm friends, and his death, at but 38 years of age, is a matter of regret to those who knew him best.

LIST OF OFFICERS AND COMMITTEES FOR 1900

President..... ....AMBROSE V. POWELL
First Vice-President....... .. EDWARD J. BLAKE
Second Vice-President.......WILLIAM H. FINLEY
Treasurer ....RALPH MODJESKI

TRUSTEES

GEO. P. NICHOLS.............................Term expires January, 1901
AUGUST ZIESING.............................Term expires January, 1902
BION J. ARNOLD..... ....Term expires January, 1903

The above named officers of the Society constitute its Board of Direction

Secretary and Librarian
NELSON L. LITTEN

STANDING COMMITTEES

On Finance—Edward J. Blake, Chairman; Ralph Modjeski, Chas. W. Melcher.

On Publication—Wm. H. Finley, Chairman, 22 Fifth Ave.; B. E. Grant, 1640 Unity Building; W. T. Keating, 577 S. Albany Ave.

On Library—Geo. P. Nichols, Chairman ; J. W. Alvord, F. P. Kellogg, Ralph Modjeski.

On Membership—August Ziesing, Chairman; Fred L. Hill, C. O. Billow.

SPECIAL COMMITTEES

On Publication—J. H. Warder, 207 City Hall; Andrews Allen, 1317 Monadnock Block; W. A. Rogers, 1100 Old Colony Building; T. W. Snow, 360 Dearborn Street, Chicago; Prof. D. C. Jackson, Madison, Wisconsin.

On Entertainment—J. J. Reynolds, Chairman; Isham Randolph, Robt W Hunt.

On Paris Exposition—Ralph Modjeski, Chairman; Isham Randolph, Thos. T. Johnston, Bion J. Arnold, Nelson O. Whitney, C T. Purdy

ABSTRACT OF MINUTES OF THE SOCIETY.

SPECIAL MEETING, October 17, 1900.

A special meeting (431st) of the Society was held in its hall at 8 o'clock, October 17, 1900, President A. V. Powell in the Chair. The first subject on the program was the further discussion of the paper on "Proposed Specifications for Steel Railway Bridges." Mr. J. W. Schaub, the author of the paper, read a discussion of the subject and the comments made on it at the previous meeting. He was followed by remarks from Messrs. H. E. Horton, A. Ziesing and others. Mr. Schaub then presented a model illustrating the action of a girder under different circumstances. The chair then presented Mr. Irving Hitz, who read an interesting paper, entitled "An Experiment With Wet and Dry Concrete." Lantern slides were used illustrating the subject. An extended discussion followed, participated in by Messrs. Liljencrantz, Hitz, E. H. Lee, E. R. Schnable and the chair, after which the meeting adjourned.

SPECIAL MEETING, October 31, 1900.

A special meeting (432d) of the Society was held in its hall at 8 o'clock, Wednesday evening, October 31, 1900. In the absence of a presiding officer, Mr. Ralph Modjeski was called to the Chair and charge of the meeting, and introduced Mr. W. S. Johnson, of Milwaukee, Wis. The subject for the evening was "Wireless Telegraphy." Mr. Johnson presented the subject in a simple, interesting manner, so that even the uninitiated could get a satisfactory understanding of the matter, which was illustrated with charts and instruments. He began with a general talk on the subject of electricity, and then went back to the first beginnings of transmitting messages without wires. At the close of the address a number of questions were propounded for explanations, which were given by Mr. Johnson. Mr. Warder moved that a vote of thanks be given Mr. Johnson; the motion was seconded and acted upon most heartily. Mr. G. P. Nichols then made a statement that the occasion was intended somewhat as an opening of the new rooms recently fitted up, and also incidentally called attention to refreshments, which were to be found in the hall. The meeting then adjourned, the rooms were visited and refreshments partaken of. There was a very good attendance, to the number of 75 ladies and gentlemen, and the expressions showed the evening to have been an enjoyable one.

The meeting adjourned after refreshments had been served.

REGULAR MEETING, November 7, 1900.

A regular meeting (433d) of the Society was held in its reading room at 8 o'clock Wednesday evening, November 7, 1900, Vice President Finley in the Chair, 30 members and guests present. The Secretary reported for the Board of Direction the receipt of applications for active membership in the Society, as follows: From John Van Wakeman, Winslow H. Foster, Samuel H. Hedges, Wensel Morava.

Mr. Bion J. Arnold called attention to the receipt of two handsomely bound books descriptive of the Eiffel tower, a gift from Monsieur G. Eiffel, and made a motion that the President be requested to prepare and send a vote of thanks of the Society to Monsieur Eiffel. The motion was duly seconded, and after brief discussion and explanation was carried.

The Chair then introduced Mr. R. B. Wilcox, engineer of the river and harbor of Chicago. "The River and Harbor of Chicago" was the subject of the paper which Mr. Wilcox read. After the reading and before taking up the discussion of the subject, the Chair stated that owing to the failure of the electric light in the main

hall of the Society, which prevented the use of the stereopticon, the next paper of the evening, on "The Robert A. Waller City Electric Lighting Plant" would be postponed.

An animated and extended discussion of the paper just read was entered into by Messrs. Liljencrantz, Wilcox, Artingstall, E. H. Lee and the Chair.

Mr. Artingstall moved that the discussion be postponed for a month in order that vessel men might have an opportunity to speak on the subject. The motion was seconded, put and carried.

A motion to adjourn followed and carried.

SPECIAL MEETING, November 21, 1900.

A special meeting (434th) of the Society was held in its hall at 8 o'clock Wednesday evening, November 21, 1900. Mr. A. V. Powell, President, in the Chair, and 38 members and guests present.

Owing to the unavoidable absence of Mr. E. B. Ellicott his paper was not read. The President then introduced Mr. Paul M. Chamberlain, of Lewis Institute, who read a paper on "The Shop and Laboratory in Relation to Engineering Education." Discussion of the paper was taken up by Mr. L. E. Cooley and Prof. C. V. Kerr. At the conclusion of the discussion the President stated that the discussion of the paper on "The River and Harbor of Chicago," read on the 7th inst., would be taken up, and called Mr. W. H. Finley, vice president, on account of his familiarity with the subject, to the chair.

Mr. Artingstall rose to a point of propriety as to the discussion of the subject at this meeting, and made motion that the paper be published and sent to members, that more time could be had for consideration of the subject. The motion not being seconded, several members suggested that as a number of gentlemen were present by invitation it would hardly be just to shut off discussion.

The Chairman requested Mr. Wilcox to state the salient points of his paper. This Mr. Wilcox proceeded to do, after which Capt. J. S. Dunham was called upon; he spoke at length on the subject and was followed by Capt. J G. Keith. Mr. L. E. Cooley, Mr. Liljencrantz and others also took part.

Before the meeting adjourned Mr. Artingstall moved that the paper with all the discussion be printed and sent to members and others interested, and a special meeting be called for further discussion.

The motion was duly seconded and carried. The Publication Committee promised to arrange for a convenient date.

The meeting adjourned.

REGULAR MEETING, December 5, 1900.

The regular meeting (435th) of the Society was held in its hall at 8 o'clock, Wednesday evening, December 5, 1900, President Ambrose V. Powell in the Chair and 35 members present.

The minutes of the last meeting were read and approved.

The Secretary then read a report for the Board of Direction, announcing the election of Messrs. Winslow H. Foster, Samuel H. Hedges and Wensel Morava as active members, and Edward H. Rodgers as junior member. The resignations of Robert Shailer, H. F. J. Porter and W. K. McFarlin were accepted.

Mr. Chas. P. Kemble, having complied with the usual requirement, was reinstated to active membership. Applications for active membership were received and referred to the Membership Committee as follows From Carlton C. Witt and Samuel Louis Jacobson.

The Chair announced that the time for nomination by petition of officers for the coming year expired with the close of this meeting.

The Chair then called for the first paper on the program, "Recent Progress in Sewage Purification," on which Prof. A. N. Talbot, the author, read a very interesting paper. The discussion was opened by Mr. W. S. Shields, and was participated in by Mr. Ossian Guthrie, Prof. F. E. Turneaure and Prof. Talbot.

The Chair introduced Mr. E. B. Ellicott, City Electrician, who read a paper descriptive of "The Robert A Waller City Electric Lighting Plant," which was discussed by Messrs. W. H. Finley, D. W. Mead, J S. Stephens and Mr. Ellicott.

The meeting adjourned.

SPECIAL MEETING, December 12, 1900.

A special meeting (436th) of the Society called to continue the discussion of the paper by Mr. R. B. Wilcox, on the River and Harbor of Chicago, was held in the Society Hall at 8 o'clock, Wednesday evening, Dec. 12, 1900, President Ambrose V. Powell in the Chair, and 36 members and guests present. A number of gentlemen were invited to be present and to speak on the subject. Mr. L. O. Goddard, being among the number, opened the discussion. Captain J. A. Calbick was then introduced, and spoke from a vessel owner's point of view. A general discussion followed, Messrs. Alfred Noble, S. G. Artingstall, R. B. Wilcox, E. Wilmann, L. O. Goddard, Capt. Calbick, B. J. Arnold and the Chair taking part in it.

At the close of the meeting, Mr. J. J. Reynolds stated that the Entertainment Committee proposed to take up the river and harbor question for the subject at the annual meeting of the Society, and give cordial invitations to societies, associations and the various persons interested in it to attend the meeting.

The Chair announced that the annual meeting would take place on Tuesday, the 8th of January, 1901, and it was hoped that opportunity would be given for preparation of formal addresses on the subject of the river and harbor, should it be fully determined to take it up for that occasion.

The meeting adjourned.

NELSON L. LITTEN, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL we have received the following gifts from the donors named:

U. S. Geological Survey, 20th Annual Report, 1898-9, Parts II, III, IV, V and VII.
" " " Map of Alaska, showing known gold-bearing rocks.
" " " Preliminary Report on Cape Nome Gold Regions.
Inter-State Commerce Com., 12th Annual Report on the Statistics of Railways in U.S.
Royal Engineers Institute, Chatham, Eng., Vol. XXV, 1899, Professional Papers Royal Engineers.
Lake Mohonk Arbitration Conference, Report 6th Annual Meeting on International Arbitration, 1900.
Michigan State Board of Health, Proceedings 4th General Conference Health Officers, October, 1899.
D. S. Hill, Asst. to Chief Engr. L. E. & W. Ry., Characteristics of the Lake Erie & Western R. R. as existing Jan. 1, 1900.
U. S. Dept. of Agriculture, Irrigation in New Jersey, 1900.
U. S. Supt. of Documents, Publications U. S. Dept. Agriculture, for sale Feb. 1, 1900.
" " " No. 67 Catalogue U. S. Pub. Documents, July, 1900.
Bruno Hessling, Catalogue of Works on Architecture, Art and Art Industry.
American Institute of Mining Engineers, List of Officers, Members, Rules, etc., October 1, 1900.
John Bruner, Supt. Engineering and Construction, Pittsburg. Annual Report Department Public Works, Pittsburg, Pa., 1899.
University of Wisconsin, Carl Hambuechen, B. Sc. Bulletin 42, An Experimental Study of the Corrosion of Iron Under Different Conditions.
Wm. S. Love, 12 Nos. Engineering Magazine, Sept. 1899, Sept. 1900.
University of Wisconsin, Geological and Natural History Survey, The Geography of the Region About Devil's Lake and The Dalles of Wisconsin.
" " Geological and Natural History Survey, The Geology of the pre-Cambrian Igneous Rocks, Fox River Valley, Wis.
" " Geological and Natural History, Survey, Preliminary Report of the Copper-bearing Rocks of Douglas County, Wis.
Illinois Society of Engineers and Surveyors, 15th Annual Report, 1900.
U. S. Coast and Geodetic Survey. The Transcontinental Triangulation.
Massachusetts State Board of Health, 31st Annual Report.
B. F. Sturtevant Co., Illustrated Catalogue of Engines.
Industrial Water Co., Water Softening and Purifying Apparatus.
" " " Pure Water for Steam Boilers.

NEW EXCHANGES.

Mechanical Progress, Manchester, Eng. A Practical Magazine for Engineers.
Journal of the Society of Mechanical Engineers, Tokyo, Japan.
Science Abstracts, m., London. Physics and Electrical Engineering.
Domestic Engineering, m., London.
Transactions British Association of Water Works Engineers, Annual, London.
Proceedings Philosophical Society of Glasgow, 1898-9, Glasgow, Scotland.
The Railroad Herald, m., Atlanta, Ga.
The Manchester Literary and Philosophical Society, Vol. XLIV, 1899-1900.
The Automobile, m., New York City.

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Vol. V.—January to December, inclusive.
1900.

Abstracts from Other Publications.

FIFTEENTH LIST

WESTERN SOCIETY OF ENGINEERS

ORGANIZED 1869
INCORPORATED SEPT. 1ST, 1880

CONSTITUTION,
BY-LAWS, LIST OF OFFICERS
AND MEMBERS

JUNE, 1900

SECRETARY'S OFFICE, READING ROOM, LIBRARY AND MEETING HALL,
1734-1741 MONADNOCK BLOCK
CHICAGO

THE WESTERN SOCIETY OF ENGINEERS

ORGANIZED IN 1869. INCORPORATED 1880.

PER ARDUA AD METAM

CONTENTS.

WESTERN SOCIETY OF ENGINEERS.

CONSTITUTION.

ARTICLE I.

NAME AND LOCATION.

SECTION 1. The name of this Association shall be the Western Society of Engineers.

SEC. 2. The offices of the Society shall be located in the city of Chicago.

ARTICLE II.

OBJECT AND MEANS.

SECTION 1. The object of this Society shall be the advancement of the science of engineering, and the best interests of the profession.

SEC. 2. Among the means to be employed shall be meetings for the reading and discussion of appropriate papers and matters of engineering interest, and for professional and social intercourse; the collection of a library, and the publication of such parts of the transactions as may be deemed expedient.

SEC. 3. The Society shall neither endorse nor recommend any individual or any scientific or engineering production, but the opinion of the Society may be expressed on such subjects as affect the public welfare.

ARTICLE III.

MEMBERSHIP.

SECTION 1. The management of this Society shall be in the hands of its Active Members. There may also be connected with the Society, Honorary Members, Juniors and Associates who shall be entitled to all the privileges of the Society, except the right to vote and hold office.

SEC. 2. An Active Member shall be a professional Engineer He shall be at the time of admission to membership at least twenty-five years of age, and shall have been in the active practice of his profession for at least five years; he shall have had responsible charge of work for at least two years. Graduation from a school of Engineering shall be considered equivalent to two years active practice. The performance of the duties of a Professor of Engineering, shall be taken as equivalent to an equal number of years of actual practice.

SEC. 3. An Honorary Member shall be a person of acknowledged eminence in some branch of Engineering, or the sciences related thereto, and who has rendered some special service to the profession.

SEC. 4. A Junior shall be not less than eighteen years of age and a person who is not eligible as an Active Member. He shall have had active practice in some branch of Engineering for at least two years, or he shall have graduated from a school of Engineering of recognized standing.

SEC. 5. An Associate shall be a person interested in the advancement of Engineering knowledge.

ARTICLE IV.

OFFICERS.

SECTION 1. The officers of the Society shall be: a President, a Vice-President, a Second Vice-President, a Secretary, a Treasurer and three Trustees. The President, Vice-President, Second Vice-President, Treasurer and Trustees shall constitute a Board of Direction in which the government of the Society shall be vested.

SEC. 2. Vacancies in any office for the unexpired term shall be filled by the Board of Direction without unnecessary delay.

ARTICLE V.

ANNUAL MEETING.

SECTION 1. The Annual Meeting shall be held on the first Tuesday after the first day of January, for the canvassing of the ballot for officers for the ensuing year, the reception of the Annual Reports and the transaction of general business.

ARTICLE VI.

AMENDMENTS.

SECTION 1. Proposed amendments to this Constitution must be reduced to writing and signed by not less than ten Active Members, and must be submitted and acted upon as follows:

SEC. 2. Amendments presented to the Secretary on or before the first Wednesday in October, shall be printed and mailed to each member at least fifteen days before the first Wednesday in November. Such amendments shall be in order for discussion at the first regular meeting in November, and may be amended in any manner pertinent to the original amendments by a majority vote at that meeting. They shall then be voted upon by letter ballot, the vote to be counted at the first regular meeting in December.

SEC. 3. An affirmative vote of two-thirds of all ballots cast shall be necessary to the adoption of any amendment. Amendments so adopted shall take effect at the next Annual Meeting.

BY-LAWS.

Amended November 1, 1899.

ARTICLE I.

MEETINGS.

SECTION 1. At the Annual Meeting of the Society twenty-five Active Members shall constitute a quorum, and the order of business shall be as follows:

1. Reading of minutes.
2. Report of the Board of Direction.
3. Announcement of the results of election.
4. Address of the retiring President.
5. Address of the President-elect.
6. Adjournment.

SEC. 2. Regular meetings for the transaction of business and the reading and discussion of papers shall be held on the first Wednesday of each month, except January. At these meetings fifteen Active Members shall constitute a quorum.

SEC. 3. The following shall be the order of business at regular meetings:

1. Reading of Minutes.
2. Report of the Board of Direction.
3. Reports of standing and special committees.
4. Unfinished business.
5. New business.
6. Reading of papers.
7. Discussion of papers and other questions.
8. Adjournment.

SEC. 4. In addition to the regular meetings, meetings for the reading and discussion of papers shall be held as ordered by the Board of Direction.

SEC. 5. Special meetings may be called by the President, and shall be called on the request of ten members, which request shall state the purpose of such meeting. The Secretary shall mail to each member of the Society, not less than one week prior to the date of such meeting, a printed notice which shall state the purpose thereof, and no other business shall be considered at such meeting At these meetings twenty Active Members shall constitute a quorum.

SEC. 6. Any member shall have the privilege of inviting friends to any meetings of the Society, except special meetings.

SEC. 7. The fiscal year shall commence with the first day of January each year.

ARTICLE II.

NOMINATION AND ELECTION OF OFFICERS.

SECTION 1. The President, Vice-President, Second Vice-President and Treasurer shall be elected annually and shall hold their offices for one year

and until their successors are elected and qualified. The Trustees shall hold office for three years, one Trustee being elected each year.

SEC. 2. The Secretary shall be elected annually by the Board of Direction at a meeting to be held within ten days after the Annual Meeting, or at an adjournment thereof, and shall hold office for one year, or until his successor is elected, provided that a majority of the entire Board of Direction shall be required to elect the Secretary, this vote to be given if necessary by letter.

SEC. 3. The Secretary shall send to each member of the Society, at least ten days before the Regular December Meeting, a copy of the By-Laws relating to the election of officers together with any special information that may be required.

SEC. 4. Candidates for each office, except that of Secretary, may be nominated by petitions subscribed to by not less than ten members of the Society. All such petitions must be addressed to the Board of Direction, and be presented at or before the Regular December Meeting. They shall be filed and open to the inspection of members, but they shall not be published.

SEC. 5. All petitions presented shall be canvassed by the Board of Direction, and if it is found that no nomination has been made for one or more officers, the Board shall make the nomination or nominations required to fill out the ticket.

SEC. 6. No member in arrears shall be eligible for office, and the President shall not be immediately eligible for re-election.

SEC. 7. Each nominee shall be promptly notified of his nomination. If any nominee shall be found by the Board of Direction ineligible for the office for which he is nominated, or should a nominee decline the nomination, his name shall not be sent out. The Board of Direction shall make additional nominations when necessary to complete one ticket, up to the time the ballots are sent out.

SEC. 8. At least ten days before the Annual Meeting there shall be sent to each Active Member a letter-ballot with envelopes for voting. This ballot shall contain all nominations made in accordance with this article. The names of nominees for any one office shall be arranged alphabetically without distinguishing marks of any kind.

SEC. 9. Each voter shall indicate his choice for each office by canceling the names of other candidates, but the number of uncancelled names for each office on the ballot voted, must not exceed the number to be elected to such office. The ballot must then be placed in a blank envelope, sealed and then enclosed in an envelope addressed to the Secretary and endorsed with the voter's signature. Ballots not complying with these provisions shall be rejected.

SEC. 10. The polls shall close at twelve o'clock noon on the day of the Annual Meeting, and the ballot shall be canvassed publicly by three Judges appointed by the President.

SEC. 11. The Secretary shall make, from the signatures on the outer envelopes a list of the voters from whom ballots are received, and shall

designate all names and mark all ballots about which there may be any question on account of any rule or By-Law of the Society. A voter may withdraw his ballot and substitute another at any time before the polls close. At the close of the polls, the Secretary shall deliver all ballots received, and the poll list to the Judges of Election. The Secretary shall furnish the Judges an alphabetical list of all Active Members in arrears, and all votes from such Members shall be rejected and returned unopened to the Member voting.

SEC. 12. The Judges shall meet at the rooms of the Society at the time of the closing of the polls. Two Judges shall constitute a quorum. In the absence of a quorum the President shall appoint to fill the vacancies. The Judges shall take the poll list and ballots from the Secretary and proceed forthwith to canvass the same as follows:

1. The ballots shall be checked and all envelopes from members not entitled to vote shall be rejected.

2. The return envelopes shall be removed and destroyed.

3. The ballot envelopes shall be opened and all irregular ballots rejected.

4. The regular ballots shall be counted, and a statement of the votes prepared and signed by the Judges.

5 The report of the Judges shall be handed to the President.

SEC. 13. At the Annual Meeting the President shall declare those candidates elected who have received a plurality of the votes cast.

SEC. 14. In case of a tie between two or more candidates for the same office, the Annual Meeting shall elect the Officer from among the candidates so tied.

SEC. 15. The Officers-elect shall assume their duties immediately upon receiving notice of their election.

ARTICLE III.

DUTIES OF OFFICERS AND COMMITTEES.

SECTION 1. The President shall have general supervision of the affairs of the Society, He shall preside at meetings of the Society and of the Board of Direction at which he may be present, shall appoint all committees not otherwise provided for, and shall be *ex-officio* member of all committees. He shall, with the Secretary, sign all contracts or other written obligations of the Society which have been approved by the Board of Direction. At the Annual Meeting the President shall present a report containing a statement of the general condition of the Society and an address.

The Vice-Presidents in order of seniority shall preside at meetings in the absence of the President, and discharge his duties in case of a vacancy in the office.

SEC. 2. The Board of Direction shall manage the affairs of the Society in conformity with the laws under which the Society is organized and the provisions of the Constitution and By-Laws. It shall hold stated meetings at least once every month. Special meetings shall be called at the written

request of three Directors, or upon the order of the President. Three members of the Board shall constitute a quorum.

The Board of Direction shall supervise the investment and care of the funds of the Society; make appropriations for specific purposes; act upon applications for membership as hereafter provided; and generally direct the business of the Society. At least one month before the Annual Meeting it shall appoint an Auditing Committee to consist of three members, no one of whom shall be a Director, whose duty shall be to examine and certify the accounts of the Treasurer and Secretary. It shall cause a record of all its proceedings to be kept and preserved by the Secretary and shall make an annual report at the Annual Meeting, transmitting the report of the Secretary, the Treasurer and of other Officers, and of Committees. It shall fill from the Active Membership of the Society, any vacancy which may occur among the Officers of the Society, but said appointment for such unexpired term shall not render the member appointed ineligible for election at the next Annual Meeting.

It shall have the power to make such rules and regulations, which are not specifically stated in these By-Laws, and which it may deem necessary for the successful management of the affairs of the Society.

Any member of the Board of Direction who shall absent himself from three consecutive and regularly called meetings of the Board without having previously obtained its consent, shall cease to be a member of the Board and the Board shall proceed to fill his place for the unexpired term. Due notice of such action shall be sent to the absent member.

The Board of Direction shall meet within ten days after the Annual Meeting and shall then appoint the following Committees: A Finance Committee, a Publication Committee and a Library Committee. Each of these Committees shall be composed of three Active Members of the Society at least one of whom shall be a member of the Board of Direction.

The assignments to these Committees shall be such that at least one member of the Finance and Library Committees and two members of the Publication Committee shall have served on the same Committee during the previous year. These Committees shall report to the Board and perform their duties under its supervision.

Sec. 3. The Treasurer shall receive all moneys from the Secretary and deposit the same to the credit of the Society in such depository as may be designated by the Board of Direction. He shall pay all bills when certified as provided by these By-Laws and by rules prescribed by the Board of Direction. He shall keep regular accounts of his receipts and expenditures, which shall be open to the inspection of the Board of Direction at all times. He shall make an Annual Report and such other reports as may be required by the Board. He may be required to give bonds, for the faithful performance of his duties, in such amount and with such sureties as the Board may require. He may receive a salary, the amount of which shall be determined annually for the succeeding year by the Board of Direction at its December meeting.

Sec. 4. The Secretary shall be, under the direction of the President and Board of Direction, the executive officer of the Society. He will be ex-

pected to attend all meetings of the Society and of the Board of Direction; prepare the business therefor and duly record the proceedings thereof.

He shall promptly issue notices of meetings, inform committees of their appointment, notify new members of their election and perform such other duties as may be imposed upon him by the Society or Board of Direction.

He shall see that all moneys due the Society are carefully collected. and without loss transferred to the custody of the Treasurer. He shall carefully scrutinize all expenditures, and use his best endeavor to secure economy in the administration of the Society.

He shall personally certify the accuracy of all bills or vouchers on which money is to be paid, and shall countersign the checks drawn by the Treasurer against the funds of the Society, when such drafts are known to him to be proper and duly authorized by the Board of Direction.

He shall conduct the correspondence of the Society and shall keep full record of the same. He shall receive all communications, and after presentation to the Society, or to the proper committee, file such as are not intended for publication.

He shall have charge of the Society's rooms and their contents ; shall keep the books, maps and other documents belonging to the Library in such order as to be easily accessible to members ; he may establish such rules and regulations, with the advice and consent of the Board of Direction, as may be deemed proper and for the best interests of the Society. He shall keep a correct record of the date of election, resignation or decease of all members and shall annually send to each member of the Society a list of members with their addresses and a record of deceased members, together with a copy of the Constitution and By-Laws.

He shall assist the Publication Committee in preparing the Journal of the Society for publication, and do such clerical and editorial work as it may require of him.

He may receive a salary, the amount of which shall be determined annually for the succeeding year by the Board of Direction at its December meeting.

Sec. 5. The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Society, shall approve all bills before payment, and shall make recommendations to the Board of Direction as to any financial business of the Society.

Sec. 6. The Publication Committee shall have general supervision of the publications of the Society and of contracts and expenditures connected therewith, but all contracts and expenditures shall be subject to the approval of the Board of Direction.

The Publication Committee shall receive and examine all papers offered to the Society. In consideration of papers offered for presentation, those papers containing matter readily found elsewhere, those especially advocating personal interests, those carelessly prepared or controverting established

facts, and those purely speculative or foreign to the purpose of the Society, shall be rejected. The committee shall determine which papers shall be read in full, and which shall be printed if read by title only. The committee may return a paper to the writer for correction and emendation, and call to its aid one or more members of special experience relating to the subject treated, either to advise on the paper or to discuss it. Such papers as in the judgment of the committee should appear in the Journal, shall promptly upon their acceptance be printed and distributed to members of all grades; others shall, with the consent of the authors, be suitably indexed and filed for reference, or the committee may make abstracts thereof, which, when approved by the authors, may be published instead of the original papers. Advance copies or abstracts of papers and discussions may be sent to the members before final publication.

Upon the request of the Publication Committee, the President shall appoint not more than five members as special members of the committee to aid in carrying out the duties herein assigned to this committee.

The committee shall, at its discretion, provide for the making and publication of abstracts of papers read before other engineering and scientific societies.

No member of the Society shall, without the consent of the Publication Committee, publish any paper as having been read before the Society, and such permission, when given, shall not be construed as being an endorsement by the Society of any statement of facts or opinions advanced in such papers or publications.

Sec. 7. The Library Committee shall have general supervision of the Library and the Rooms of the Society and the property therein; shall make recommendations to the Board with reference thereto, and shall direct the expenditure for books and other articles of permanent value, of such sums as may be appropriated for these purposes.

ARTICLE IV.

ADMISSION TO THE SOCIETY.

Section 1. All elections to membership in this Society shall be made by the Board of Direction. Seven (7) affirmative votes shall be required for the election of an Honorary member, and six (6) for the election of an Active member, Associate or Junior, these votes to be cast by letter ballot, if necessary.

Sec. 2. Honorary Members shall be proposed in writing by at least fifteen Active Members, who shall state the reasons for the proposal, and shall certify that the nominee will accept if elected. A person elected as Honorary Member shall be promptly notified by letter of his election. The election shall be cancelled if an acceptance is not received within three months after the mailing of such notice.

Sec. 3. Associate Members shall be proposed in writing by at least five members of the Society, who shall state the reasons for the proposal and shall certify that the nominee will accept if elected.

SEC. 4. An application for admission to the Society as Active Member or Junior, or for transfer from Junior to Active Member, shall embody a concise statement, with dates, of the candidate's professional training and experience; and shall be in a form and in such detail as may be prescribed by the Board of Direction. It shall be signed by the applicant, and shall contain a promise to conform to the requirements of membership, if elected, and shall be accompanied by a deposit of Five Dollars, to be applied on entrance fee if the applicant be elected, or refunded to him if not elected. The application shall be signed by at least three Active Members to whom the applicant is personally known. Applications of Engineers who may be so situated as not to be personally known to three Active Members may be recommended for membership by three members of the Board of Direction, after having secured evidence sufficient, in their opinion, to show that the applicant is worthy of admission.

SEC. 5. All applications shall be presented and read at a regular meeting of the Board of Direction, and if received, shall be placed on file until the succeeding or some subsequent regular meeting, at which time they shall be again read and submitted to a vote.

The names of all applicants received by the Board shall be posted in the rooms of the Society, and sent to each member so as to give opportunity for members to submit objections to any candidates.

SEC. 6. Within one year after the date of the vote, the Board of Direction, upon the receipt of letters from not less than five Active Members in good standing, requesting a reconsideration of the vote on any excluded candidate and stating the reasons for such request, shall consider these reasons, and if the Board deems them sufficient, it shall reconsider the vote upon which the applicant was formerly rejected.

SEC. 7. Each elected candidate shall be duly notified and shall subscribe to the Constitution and By-Laws, and pay his entrance fee and dues. If these provisions are not complied with within three months from the notification of election, such election shall be void unless for special reason the time shall be extended by the Board of Direction. Membership of any person shall date from the date he subscribes to the Constitution and By-Laws and pays his dues.

SEC. 8. A member of any grade in the Society may resign his membership by a written communication to the Secretary, who shall present the same to the Board of Direction at their next meeting; when, if all of his dues shall have been paid, his resignation shall be accepted.

SEC. 9. All persons elected and duly qualified, whose address on the records of the Society is within fifty miles of the post office in the city of Chicago, shall be deemed resident; and those whose address is beyond that limit shall be deemed non-resident.

The classification of any member for the fiscal year as resident or non-resident, shall be determined by the records of the Society as they may appear on January 1st of that year.

ARTICLE V.

DISCIPLINE.

SECTION 1. The Society shall have power to hear and determine upon the conduct of its members for any infraction of its rules and regulations, and for professional misconduct calculated to affect the good name of the Society, or interfere with order and harmony.

SEC. 2. Upon the written request of ten or more Active Members, that for cause therein set forth a person belonging to the Society be expelled, the Board of Direction shall consider the matter, and if there appears to be sufficient reason, shall advise the accused of the charges against him. He may, if he so desires, present a written defense which shall be considered at a meeting of the Board of Direction, of which he shall receive due notice. Not less than two months after such meeting the Board of Direction shall finally consider the case, and if resignation has not been tendered, or a defense made which is satisfactory to the Board, it shall then notify the person that he will be expelled in one month, unless he elects to appeal from this decision. Appeals will be submitted to the Active Members by letter-ballot in a form to be prescribed by the Board of Direction. The ballot shall be accompanied by a statement of the charges, and the action of the Board thereon, with such information as it deems proper, and also the statement of the person making the appeal. The ballot shall be canvassed by the Board not less than twenty days after its issue. A majority of the ballots cast will be required to sustain the action of the Board. The Board will notify the person and the Active Members of the result of the ballot. In case no appeal be made, the Board of Direction will expel the person, and notify him and the Active Members of its action.

SEC. 3. Any person expelled from this Society shall not be restored thereto.

SEC. 4. No Disciplinary proceedings of the Society shall be given any publicity whatever.

ARTICLE VI.

FEES AND DUES.

SEC. 1. An entrance fee of Ten Dollars shall be payable on admission to the Society by Active Member or Associate, and Three Dollars by a Junior, this sum to be credited against entrance fee at the time of his transfer to another grade. A Junior's connection with this Society shall cease when he becomes thirty years of age unless he be previously transferred to another grade.

SEC. 2. Honorary Members shall be subject to no entrance fees or dues.

SEC. 3. The annual dues payable by members, whether resident or non-resident shall be as follows: by Active Members, \$7.50, Associates, \$7.50; Juniors, \$5.00.

SEC. 4. In addition to the dues prescribed in the preceding section, Resident Members shall pay annually as follows: Active Members, \$2.50; Associates, \$2.50.

SEC. 5. The annual dues shall be payable in advance and shall become due on the 15th day of January for the ensuing year. It shall be the duty of the Secretary to notify each member of the amount due for the ensuing year within three days after the Annual Meeting.

SEC. 6. Persons elected to any grade of membership in the Society after the first two (2) months of any fiscal year have expired, shall pay only such amount of dues for that fiscal year as is proportional to the part of the year remaining. For the purpose of reckoning the proportional amount of dues to be paid, the year shall be divided into six periods of two months each.

SEC. 7. Any person whose dues are more than three months in arrears shall be notified by the Secretary. Should the dues not be paid when they become six months in arrears, he shall lose the right to vote or to receive the publications of the Society. Should his dues become nine months in arrears, he shall again be notified in form prescribed by the Board of Direction, and if such dues become one year in arrears, he shall forfeit his connection with the Society. The Board of Direction, however, may for cause deemed by it sufficient, extend the time for payment and for the application of these penalties.

SEC. 8. The Board of Direction may, for sufficient cause, temporarily excuse from payment of annual dues any member who from ill-health, advanced age, or other good reason assigned, is unable to pay such dues; and the Board may remit the whole or part of dues in arrears, or accept, in lieu thereof, desirable additions to the Library, or collections.

SEC. 9. Every person admitted to the Society shall be considered as belonging thereto and liable for the payment of all dues until he shall have resigned, been expelled, or have been relieved therefrom by the Board of Direction.

ARTICLE VII.

MISCELLANEOUS.

SECTION 1. In all questions involving parliamentary rules "Robert's Rules of Order" shall be the governing authority.

SEC. 2. Members of this Society of every grade who shall have been such for at least one year and have complied with the provisions of the Constitution and By-Laws shall be entitled to a diploma, certifying the grade of membership, which shall be signed by the President and attested by the Secretary under the seal of the Society.

SEC. 3. The following are hereby declared to be the authorized abbreviations to be used by the members of the Society having occasion to designate themselves as such:

For Active Members.............................M. W. S. E.
" Honorary Members.......................Hon. M. W. S. E.
" Juniors......................................Jun M. W. S. E.
" Associate Members.....................Assoc. M. W. S. E.

ARTICLE VIII.

AMENDMENTS.

Section 1. Proposed amendments to these By-Laws must be reduced to writing, signed by at least three Active Members, and presented at a regular meeting of the Society. They may then be amended by a majority vote of the meeting. They shall then be submitted to a vote by letter-ballot, the vote to be counted at the next regular meeting. An affirmative vote of two-thirds of all ballots cast shall be necessary to the adoption of an amendment. Amendments so adopted shall take effect immediately.

WESTERN SOCIETY OF ENGINEERS.

PAST PRESIDENTS.

*Roswell B. Mason	June 14, 1869 to June 13, 1870
Charles Paine	June 13, 1870 to June 9, 1873
*E. S. Chesbrough	June 9, 1873 to June 19, 1877
Wm. Sooy Smith	June 19, 1877 to Aug. 3, 1880
*E. S. Chesbrough	Aug. 3, 1880 to Jan. 2, 1882
*Willard S. Pope	Jan. 2, 1882 to Jan. 8, 1883
*Dewitt C. Cregier	Jan. 9, 1883 to Jan. 6, 1885
Benezette Williams	Jan. 6, 1885 to Jan. 5, 1886
Augustine W. Wright	Jan. 5, 1886 to Jan. 4, 1887
Samuel G. Artingstall	Jan. 4, 1887 to Jan. 3, 1888
*A. Gottlieb	Jan. 3, 1888 to Jan. 8, 1889
E. L. Corthell	Jan. 8, 1889 to Jan. 8, 1890
L. E. Cooley	Jan. 8, 1890 to Feb. 3, 1892
Isham Randolph	Feb. 3, 1892 to Jan. 4, 1893
Robert W. Hunt	Jan. 4, 1893 to Jan. 3, 1894
Hiero B. Herr	Jan. 3, 1894 to Jan. 2, 1895
Horace E. Horton	Jan. 2, 1895 to Jan. 2, 1896
John F. Wallace	Jan. 2, 1896 to Jan. 5, 1897
Thos. T. Johnston	Jan. 5, 1897 to Jan. 4, 1898
Alfred Noble	Jan. 4, 1898 to Jan. 3, 1899
Onward Bates	Jan. 3, 1899 to Jan. 2, 1900

*Deceased.

WESTERN SOCIETY OF ENGINEERS.

SECRETARY'S OFFICE, READING ROOM AND LIBRARY,
1734-5-6-7 Monadnock Block.

MEETING HALL,
1738-39-40-41 Monadnock Block.

LIST OF OFFICERS FOR 1900.

President.
AMBROSE V. POWELL.

First Vice-President,
EDWARD J. BLAKE.

Second Vice-President,
WILLIAM H. FINLEY.

Treasurer,
RALPH MODJESKI.

TRUSTEES.

Term expires January 1901,
GEO. P. NICHOLS.

Term expires January 1902,
AUGUST ZIESING.

Term expires January 1903,
BION J. ARNOLD.

The above named officers of the Society constitute its Board of Direction.

Secretary and Librarian,
NELSON L. LITTEN.

MEETINGS.

Annual Meeting: Tuesday after the 1st day of January.
Regular Meetings: 1st Wednesday of each month except January.
Special Meetings: 3rd Wednesday evening of each month.
Board of Direction: The Monday preceding the first and third Wednesday of each month.

COMMITTEES.

STANDING COMMITTEES.

On Finance.

Edward J. Blake, Chairman; Chas. W. Melcher, Ralph Modjeski.

On Publication.

Wm. H. Finley, Chairman, Room 22 Fifth Ave.; B. E. Grant, 1640 Unity Bldg.; Wm. T. Keating, 577 So. Albany Ave.

On Library.

Geo. P. Nichols, Chairman; J. W. Alvord, F. P. Kellogg.

On Membership.

August Ziesing, Chairman; Fred L. Hill, C. O. Billow.

SPECIAL COMMITTEES.

On Publication.

J. H. Warder, 207 City Hall; T. W. Snow, 360 Dearborn St., W. A. Rogers, 1100 Old Colony Bldg.; Andrews Allen, 1317 Monadnock Block, Chicago; Prof. D. C. Jackson, care of Univ. Wis., Madison, Wis.

On Entertainment.

James J. Reynolds, Chairman; Isham Randolph, Robt. W. Hunt.

On Paris Exposition.

Ralph Modjeski, Chairman; Isham Randolph, Thos. T. Johnston, Bion J. Arnold, Nelson O. Whitney, C. T. Purdy.

LIST OF MEMBERS.*

HONORARY MEMBER.

(Hon. M. W. S. E.)

NAME	ELECTED
MOREHOUSE, L. P., (*Past-Secretary.*) Custodian of Deeds Illinois Central Railroad, No. 1 Park Row, Chicago, Ill.	M. May 25, 1869 Hon. M. Dec. 7, 1887

ACTIVE MEMBERS.

(Active M. W. S. E.)

NAME	ELECTED
ABBOTT, HERMAN R., Res. Engr. Zion Land & Investment Asso., Foss, Lake Co., Ill.	Oct. 3, 1894
ADAMS, GEO. T., Sanitary District of Chicago, 1010 Security Bldg., Chicago.	Mar. 1, 1898
ALLAN, JOHN B., Mgr Chicago Office, The Edward P. Allis Co., 509 Home Ins. Bldg., Chicago.	Jan. 19, 1897
ALEXANDER, H. B., Asst. Eng. Sanitary Dist. of Chicago, Geneva, Ill.	May 4, 1880
ALLEN, ANDREWS, Contracting Engineer Wisconsin Bridge Co., 1317 Monadnock Block, Chicago.	Mar. 11, 1899
ALVORD, JOHN WATSON, Alvord & Shields, Civil, Sanitary and Hydraulic Engineers, 127 Hartford Bldg., Chicago.	Oct. 6, 1885
AMES, GEO. MARSHALL, Civil Engineer, 350 Crescent Ave., Grand Rapids, Mich.	Mar. 5, 1895
ANGIER, WALTER EUGENE, Asst. Engineer Ill. Central R. R., Chicago.	July 1, 1899
ANTHONY, F. D., Asst. Engineer G. N. Ry., West Chicago, Du Page Co., Ill.	Dec. 10, 1897
APPLETON, THOMAS, Chief Engineer Copper Range R. R., Houghton, Mich.	April 8, 1891
ARNOLD, BION J., (*Trustee*) Consulting Electrical Engineer, 1540 Marquette Bldg., Chicago.	Dec. 1, 1896
ARTINGSTALL, SAMUEL GEORGE, (*Past-President*). Civil Engineer, 240 Rialto Bldg., Chicago.	Jan. 2, 1877
ASHMEAD, PERCY HERBERT, Civil Engineer with G. & Q. R. R., Guayaquil, Ecuador.	Dec. 5, 1894
BABCOCK, W. IRVING, Pres. Chicago Shipbuilding Co., 1125 The Rookery, Chicago.	Jan. 2, 1895
BABO, ALEXANDER VON, Bridge Dept., City Hall, Room, 227 Chicago.	April 4, 1894
BADT, FRANCIS B. Prest. Badt-Goltz Engineering Co., 1504 Monadnock Block, Chicago.	Mar. 1, 1898

* NOTE.—In the interest of all concerned, it is urged upon members to report every change of address promptly to

SECRETARY
WESTERN SOCIETY OF ENGINEERS,
1737 Monadnock Block, CHICAGO, ILL.

NAME	ELECTED
BAINBRIDGE, FRANCIS HENRY, Asst. Engineer C. & N. W. Ry., 22 Fifth Ave., Room 30, Chicago.	Nov. 27, 1893
BAKER, IRA OSBORN, Prof. of Civil Engineering University of Illinois, 702 W. University Ave., Champaign, Ill.	Aug. 3, 1886
BALDWIN, HENRY FURLONG, Chief Engineer, C. & A. Ry., 922 Monadnock Block, Chicago.	July 1900
BALDWIN, WALTER H., Sales Manager Lidgerwood Mfg. Co., 1510 Old Colony Bldg., Chicago.	Jan. 19, 1897
BARCROFT, FREDERICK T., Civil Engineer, Joy and Barcroft, Architects and Engineers, 407-8 Ferguson Bldg., Detroit, Mich.	May 2, 1900
BARKER, FRANK W., Pres. Kenwood Bridge Co., Room 417 First Nat. Bank Bldg., Chicago.	Feb. 4, 1891
BARRINGTON, EDWARD, Principal Asst. Engineer Vera Cruz & Pacific Ry.—P. O. Box 2015 Ciudad, Mexico.	May 3, 1881
BATES LINDON W., Engineer and Contractor, 43 Threadneedle St., London, E. C.	Oct. 3, 1894
BATES, ONWARD, (*Past-President*), Engineer and Superintendent of Bridges and Bldgs., C. M. & St. P. Ry. and D. M. N. & W. R. R., 1100 Old Colony Bldg., Chicago.	Oct. 24, 1890
BEARDSLEY, JAMES WALLACE, U. S. Surveyor, 93 Park St., Oshkosh, Wis.	Dec. 21, 1892
BECKLER, ELBRIDGE, H., Civil Engineer, Richmond, Ill.	Jan. 19, 1897
BELL, CHARLES H., Calle 48, No. 679 La Plata, Argentine Republic, So. A.	Aug. 6, 1896
BERGE, HOWARD, With D. H. Burnham & Co., 1142 The Rookery, Chicago.	April 30, 1895
BERGENDAHL, GUSTAVE STORM, With Chicago Bridge & Iron Co., Washington Heights, Chicago.	May 13, 1899
BERKELEY, ROBERT CARTER, Civil Engineer, 512 Dooly Block, Salt Lake City, Utah.	Feb. 25, 1896
BEYE, JOHN C., Division Engineer, Kansas Division U. P. R. R., 12th and Liberty Sts., Kansas City, Mo.	Mar. 3, 1893
BILLIN, CHARLES EMERY, Chas. E. Billin & Co., 1543 Marquette Bldg., Chicago,	Jan. 5, 1886
BILLOW, CLAYTON O., Consulting Engineer, 315 Dearborn St., Chicago.	Mar. 17, 1896
BINDER, CARL, Civil Engineer and Contractor, Structural Iron and Aerial Rope Tramways, 803-6 Schiller Bldg., 103 Randolph St., Chicago.	Dec. 1, 1886
BINKLEY, GEO. HOLLAND, Chief Engineer Calumet Electric St. Ry., 9314 Drexel Ave., Chicago.	Sept. 9, 1899
BLAKE, EDWARD JOSIAH, (*1st Vice-President*) Consulting Engineer, C. B. & Q. R. R., Room 67, 209 Adams St., Chicago.	Nov. 7, 1894
BLEY, JOHN CORNELIUS Mechanical Engineering Vulcan Iron Works, 59 Milwaukee Ave., Chicago.	Sept. 7, 1895
BLUNT, JOHN E., Consulting Engineer C. & N. W. Ry., 22 Fifth Ave., Room 30, Chicago.	June 14, 1899
BOARDMAN, HORACE PRENTISS, Asst. Engineer C. & A. Ry., 922 Monadnock Block, Chicago	Dec. 5, 1894
BOEDKER, HAROLD ANDREW, Pres. H. A. Boedker & Co., R. R. Contractors, 1208, 355 Dearborn St., Chicago.	July 11, 1894
BOGUE, VIRGIL GAY, Room 118, 66 Broadway, N. Y. City.	Dec. 20, 1893
BRACE, JAMES H. Care of Board of Engineers, U. S. Deep Waterways, 34 W. Congress St., Detroit, Mich.	Dec 20, 1893

NAME	ELECTED
BRAINARD, C. V., U. S. Asst. Engineer, Illinois River Imp., Kampsville, Calhoun Co., Ill.	April 2, 1895
BRANSFIELD, JAMES T., 2020 39th St., Chicago.	April 15, 1899
BRECKENRIDGE, LESTER PAIGE, Prof. of Mechanical Engineering University of Illinois, Urbana, Ill.	Oct. 28, 1899
BRECKENRIDGE, W. L., Chief Engineer C. B. & Q. R. R., Chicago.	July 3, 1899
BREMNER, GEO. H., Div. Engineer C. B. & Q. R. R., 67 General Offices, 209 Adams St, Chicago. Not a member in 1893-4-5.	Oct. 4, 1887
BRINCKERHOFF, HENRY MORTON, General Mgr. Metropolitan West Side Elevated Ry., 1001 Royal Insurance Bldg., Chicago.	Feb. 25, 1896
BROWN, FREDERICK S., Contractor, Bridge Masonry, 240 LaSalle St., Chicago.	April 2, 1890
BROWN, JOHN HENRY, Sewer Department, 207 City Hall, Chicago.	July 5, 1893
BROWN, MELVILLE, Division Engineer, B. C. R. & N. Ry., Cedar Rapids, Iowa.	Feb. 3, 1892
BROWN, ROBERT P., 217 City Hall, Chicago.	June 5, 1889
BRYANT, B. H., Gen'l Supt. Colorado Midland Ry., Colorado Springs, Colo.	Nov. 6, 1877
BULL, STORM, Prof. of Steam Engineering University of Wisconsin, Madison, Wis.	Jan. 28, 1899
BURKE, RICARD O'SULLIVAN, Civil Engineer, Asst. Engineer Bureau of Engineering, City Hall, Chicago.	Mar. 6, 1899
BUSH, LINCOLN, Bridge Engineer, D. L. & W. R. R., Hoboken, N. J.	Dec. 30, 1890
BUTLER, GEORGE ARTHUR, With Chicago Transfer & Clearing Co., 6730 Normal Ave., Chicago.	Dec. 30, 1890
CANFIELD, JOHN THOMAS, San Fernando, Durango, Mexico.	Mar. 21, 1900
CARTER, BYRON B., Consulting Mech. Engineer, 1223 Monadnock Block, Chicago,	Feb. 25, 1896
CARTER, EDWARD CARLOS, Chief Engineer, C. & N. W. Ry., 22 Fifth Ave., Chicago.	Sept. 14, 1877
CARTER, HENRY W., Carter & Graves, Patent Lawyers, 1261 Monadnock Block, Chicago.	May 4, 1897
CARTLIDGE, CHARLES HOPKINS, Bridge Engineer, Chief Engineer's Office C. B. & Q. R. R., Room 67, 209 Adams St., Chicago.	Mar. 21, 1900
CARUTHERS, WILLIAM S., Asst. Eng. Union Pacific R. R., Denver, Colo.	Jan. 2, 1900
CASGRAIN, WILLIAM T., Engineer and Supt. for James Stewart & Co., St. Louis, Mo.	Feb. 7, 1888
CHAMBERLAIN, PAUL MELLEN, Asso. Prof. of Engineering, Lewis Institute Chicago.	July —, 1900
CHANDLER, GEORGE W., City Engineer, Canton, Ill.	July 5, 1893
CHANUTE, OCTAVE, Consulting Engineer, 413 E. Huron St., Chicago.	July 12, 1869
CHASE, CHARLES P., Manager Iowa Engineering Co., Hydraulic and Sanitary, 410-411 Weston Block, Clinton, Iowa.	Mar. 24, 1897
CHILDS, OLIVER W., Chief Engineer for Stupp Bros., B. & I. Co., 2301 S. Seventh St., St. Louis, Mo.	Mar. 3, 1891
CHRISTIE, GEORGE B., Christie & Lowe, 171 La Salle St., Chicago.	Jan 2, 1895

NAME		ELECTED
CHRISTIE, WILLIAM MUNSON, Sanitary District of Chicago, Room 1209 Security Bldg., Chicago.	Junior Active Mem.	Mar. 31, 1899 Mar. 21, 1900
CLARK, EUGENE BRADLEY, Electrical Engineer Illinois Steel Co., So. Chicago.		Oct. 1, 1898
CLARKSON, JAMES F., Prendergast & Clarkson, Room 5, 159 LaSalle St., Chicago.		Mar. 24, 1897
CLOUD, JOHN W., Vice-President, Westinghouse Brake Co., Ltd., York Road, Kings Cross, London, England.		June 7, 1893
COLE, EDWARD S., Asst. Engineer to John A. Cole, C. E., 1580 Old Colony Bldg., Chicago.		Sept. 2, 1898
COLE, GEORGE, Asst. Eng. I. C. R. R., care Chief Engineer's office, Central Station, Chicago.		Mar. 21, 1900
COLEMAN, JAMES P., Room 902, 1 Park Row, Chicago.		Mar. 5, 1890
COLTON, SIMEON C., Supt. The Fitz-Simons & Connell Co., 1014 Tacoma Bldg., Chicago.		Mar. 1, 1887
COMSTOCK, ADAM, Railway and Municipal Engineering and Surveying, 311 Barber Bldg., Joliet, Ill.		July 12, 1869
COMSTOCK, LOUIS K., Electrical Engineer, care of Western Electric Co., Chicago.		April 30, 1895
CONDRON, THEODORE LINCOLN, Res. Engineer, Pittsburg Testing Laboratory Ltd., 1750 Monadnock Block, Chicago.		Nov. 7, 1894
CONNOLLY, PATRICK HENRY, City Engineer, Racine, Wis.		Nov. 7, 1894
COOKE, GEORGE H., Asst. Eng. Southern Ind. Ry. Co., Bedford, Ind.		Mar. 24, 1897
COOLEY, ERNEST L., 1010 Security Bldg., Chicago.		Dec. 2, 1891
COOLEY LYMAN EDGAR, (*Past-President*), Civil Engineer, 21 Quincy St., Chicago.		June 15, 1875
COPELAND, FREDERICK K., Pres. Sullivan Machinery Co., Mfrs. Mining Machinery, 54 N. Clinton St., Chicago. Not a member in 1894-5-6.		Oct. 5, 1882
CORTHELL, ELMER LAWRENCE, (*Past-President*), Consulting Engineer, No. 1 Nassau St., New York City.		Feb. 7, 1888
COX, ARTHUR J., Westville, Miss.		Sept. 7, 1897
COX, JAMES BRADY, Chief Engineer Chicago Junction Ry., R. 180 Exchange Bldg., U. S. Yards, Chicago.		Oct. 28, 1899
CRABBS, CLARENCE L., Asst. Engineer in Charge Sec. 2, Land Tunnel, 6501 LaFayette Ave., Chicago.		Jan. 4, 1893
CRISSY, JOHN WATERBURY, Asst. Eng. Illinois Central R. R., New Orleans, La.		Mar. 17, 1896
CROSS, MOULTON J., With Sanitary District of Chicago, 1008 Security Bldg., Chicago.		Aug. 1, 1894
CURTIS, WALTER WHALEY, Civil Engineer and Contractor, 549 Marquette Bldg., Chicago.		Dec. 2, 1891
DART, CARLTON ROLLIN, Civil Engineer with Lassig Bridge Works, Chicago		Feb. 3, 1892
DAVIDSON, FRANK EUGENE, 703 Fisher Bldg., Chicago.		Jan. 3, 1890
DAVIDSON, GEORGE M., Chemist and Engineer of Tests, C. & N. W. Ry. Co., 22 Fifth Ave., Chicago		Jan. 11, 1897
DAVIES, FREDERICK HENRY, Resident Engineer B. & O. R. R., Walkerton, Indiana.		April 6, 1892
DAVIS, CARL E., Sub-Asst. Engineer, Sanitary Dist. of Chicago, 1615 So. Harding Ave., Chicago.		Sept. 28, 1891

NAME	ELECTED
DAVIS, CHARLES HENRY, Consulting Engineer, 99 Cedar St., New York City, N. Y.	Mar. 7, 1900
DAVIS, FRED, Engineer, Newport, Penobscot Co., Me.	Aug. 5, 1889
DAVIS, GARRETT, Asst. Chief Eng. B. C. R. & N. Ry., Box 357, Cedar Rapids, Ia.	May 11, 1892
DAWLEY, WILLIAM S., Chief Engineer C. & E. I. R. R., 902-355 Dearborn St., Chicago.	April 2, 1895
DEIMLING, JAMES F., Engineer, Maintenance Way, L. S. & I. Ry., Marquette, Mich.	May 11, 1892
DELANO, FREDERICK A., Supt. Motive Power, C. B. & Q. R. R. Co., Chicago.	Mar. 24, 1897
DENNIS, WILLIAM FRANKLIN General Contractors, Gooch, Rinehart & Dennis, Clarksburg, W. Va.	Dec. 5, 1894
DIXON, JUNIUS S., Supt. South Station People's Gas Light & Coke Co., Loomis and 25th St., Chicago.	June 1, 1897
DOBSON, FRANKLIN PIERCE, Consulting Engineer (Railways), P. O. Box 765, Chicago, Ill.	Nov. 17, 1896
DORST, JOHN C., Resident Agent of Massillon Bridge Co., Massillon, Ohio, 760 Monadnock Block, Chicago.	June 5, 1900
DOSE, HENRY FREDERICK, Asst. Engineer U. S. Board of Engineers, Deep Waterway, Detroit, Mich.	June 5, 1896
DOUGHERTY, CURTIS, Roadmaster I. C. R. R., 904 Central Station, Park Row, Chicago.	April 2, 1890
DRAPER, HENRY C., Asst. Engineer Chicago & Alton Ry., 922 Monadnock Block, Chicago.	Mar. 7, 1882
DUN, JAMES, Chief Engineer A. T. & S. F. R. R., Topeka, Kan.	Mar. 17, 1896
DURYEA, EDWIN, JR., 160 Cumberland St., Brooklyn, New York.	Feb. 3, 1892
ELLICOTT, EDWARD BEACH, City Electrician, Chicago.	July 1900
ELLIOTT, WILLIAM HENRY, Signal Engineer, C. M. & St. P. Ry., Milwaukee, Wis.	June 20, 1900
ELMER, HOWARD NIXON, Mgr. Chicago Office Trenton Iron Co., 1114 Monadnock Block, Chicago.	Nov. 7, 1894
ENOS, ZIMRI A., Engineer and Surveyor, 434 N. 2d St., Springfield, Ill.	Nov. 6, 1878
ERICSON, ERIC GUSTAF, Engineer M. of Way Penna. Co., Ft. Wayne, Ind.	May 4, 1886
ERICSON, JOHN, City Engineer, 325 City Hall, Chicago.	May 4, 1886
ERIKSEN, ERIC T., Sub-Asst. Engineer Sanitary Dist. of Chicago, 1010 Security Bldg., Chicago.	Mar. 3, 1891
EUSTACE, J. H., Engineer People's Gas L. & C. Co., Michigan Ave. and Adams St., Chicago.	Mar. 1, 1898
EVANS, LOUIS HYDE, Principal Asst. Engineer D. L. & W. R. R., Hoboken, N. J.	Feb. 3, 1892
EVANS, WALLACE C., Civil Engineer, 100 Y. M. C. A. Bldg., Peoria, Ill.	Jan. 17, 1894
EWALD, FRANK G., Consulting Engineer R. R. & W. H. Commission, Springfield, Ill.	May 7, 1890
EWEN, JOHN MEIGGS, 16 Hill St., Finsburg, E. C., London, Eng.	May 7, 1890
EWING, WILLIAM BION, Civil Engineer, 1003 Chamber of Commerce, Chicago.	Dec. 2, 1891
FELDMAN, A. M., Assoc. Professor Mechanical Engineering, Armour Institute of Technology, Chicago.	Mar. 5, 1895

NAME	ELECTED
FIERO, ALFRED WINFIELD, R. W. Hunt & Co., 1121 The Rookery, Chicago.	June 1, 1886
FINLEY WILLIAM H., *(2nd Vice President)* Engineer of Bridges C. & N. W. Ry., Room 30, 22 Fifth Ave., Chicago.	Nov. 7, 1894
FISCHER, F. WILLIAM, Civil Engineer and Architect, Room 210, 9206 Commercial Ave., Chicago.	Nov. 7, 1889
FISHER, SAMUEL BROWNLEE, Chief Engineer M. K. & T. R. R. Co., 406 Wainwright Bldg., St. Louis, Mo.	Nov. 11, 1889
FITZ-SIMONS, CHARLES, 1012 Tacoma Bldg., Chicago.	May 6, 1879
FOOTE, ERASTUS, Pres. Dearborn Foundry Co., 1525 Dearborn St., Chicago.	May 3, 1881
FORCE, JOHN P., Sanitary and Hydraulic Engineer, 89 So. Monroe Ave., Columbus, Ohio.	June 15, 1891
FORSYTH, ROBERT, 1143 The Rookery, Chicago.	Feb. 5, 1878
FOSTER, CHARLES FREDRIC, Mechanical Engineer, 1407 Manhattan Bldg., Chicago.	May 5, 1896
FRANSON, CHARLES FRIEDOLF, Engineer for James Stewart & Co., Lincoln Trust Bldg., St. Louis, Mo.	Nov. 11, 1889
FRENCH, EDGAR, Resident Engineer G. T. Ry., Brush St. Depot, Detroit, Mich.	Oct. 5, 1892
GASCHE, FERD G., Mechanical Engineer So. Works, Illinois Steel Co., South Chicago, Ill.	Jan. 2, 1895
GATES, ANDREW W., Engineer, care of Monmouth Mining & Mfg. Co., Monmouth, Ill.	April 4, 1894
GERBER, EMIL, Chief Engineer Lassig Bridge & Iron Works, 348 Belden Ave., Chicago.	June 2, 1890
GIBSON, JOSIAH, Bridge Draughtsman, La Grange, Ill.	July 1900
GIDDINGS, FRED, City and County Engineer, 921 Kansas Ave., Atchison, Kan.	Feb. 1, 1887
GIFFORD, ROBERT L., Civil Engineer, L. & M., Adams Express Bldg., Chicago.	Jan. 11, 1897
GILLINGHAM, WILLIAM J., JR., Signal Engineer Illinois Central R. R., R. 902, 1 Park Row, Chicago.	April 5, 1893
GODDARD, LESLIE WARREN, U. S. Asst. Engineer, U. S. Engr. Office, Grand Rapids, Mich.	Oct. 5, 1886
GOLDMARK, HENRY, Civil Engineer, 29 Broadway, New York City.	Dec. 20, 1893
GOODRICH, HARRY CLINTON, Mgr. American Fruit Growers Union, 53 River St., Chicago.	Jan. 3, 1899
GOULD, CHARLES LINNAEUS, Treas. Chicago Crushed Stone Co., 928 Stock Exchange Bldg., Chicago.	Mar. 5, 1895
GRAHAM, WILLIAM, Chief Engineer's Office, U. P. R. R., 1117 S. 33rd St., Omaha, Neb.	July 11, 1894
GRANT, BERTRAND EUGENE, Hill & Grant, Civil Engineers, 1640 Unity Bldg., Chicago	Nov. 24, 1890
GRAY, ELAM, 1553 Monadnock Block, Chicago.	Mar. 3, 1891
GREEN, ANDREW H., Pres. Green's Dredging Co., 178 So. Water St., Chicago.	Mar. 15, 1898
GREEN, OLIVER B., 403 La Salle Ave., Chicago	July 12, 1889
GUTHRIE, OSSIAN, 1213 New York Life Bldg., Chicago	Sept. 4, 1889

NAME	ELECTED
HADWEN, T. LOVELL D., Asst. Engineer B. & B. Dept., C. M. & St. Paul Ry., 1100 Old Colony Bldg., Chicago.	May 13, 1899
HAGAR, EDWARD M., Mgr. Cement Dept. Illinois Steel Co., 1060 The Rookery, Chicago.	July 30, 1898
HARDING, JAMES JUDSON, With Chicago, Milwaukee & St. Paul Ry. Co., Chicago.	Mar. 7, 1900
HARMAN, JACOB ANTHONY, Civil Engineer, Room 21-23 Arcade Bldg., Peoria, Ill.	Sept. 26, 1890
HARRISON, CHARLES LEWIS, With Denver Union Water Co., Denver, Colorado.	Dec. 30, 1890
HARVEY, ALFRED ERNEST, Roadmaster 8th Division I. C. R. R., Dubuque, Ia.	Jan. 3, 1899
HATCH, FRANK C., Simons, Hatch & Whitten Co., 32 Otis St., Boston, Mass.	Nov. 7, 1894
HAWKINS, MELVILLE S., Supt. Oliver Iron Mining Co., Mountain Iron, Minn. Not a member in 1895-6-7-8-9.	Mar. 1, 1893
HAYNES, ARTHUR MORTON, Asst. Engr. Union Pacific Ry., Rawlins, Wyoming.	Mar. 7, 1900
HEALEY, JAMES M., Civil Engineer, 77 Idaho St., Denver, Col.	Oct. 5, 1880
HECK, FRANK F., Prin. Asst. Engineer C. J. Ry., 180 New Exchange Bldg., Union Stock Yards, Chicago.	June 2, 1890
HEER, PETER, Manufacturer of Engineering Instruments, 232 E. Washington St., Chicago.	Jan. 4, 1887
HEGARDT, GUSTAVE BERNARD, U. S. Asst. Engineer, Fort Stevens, Oregon.	May 4, 1886
HEGELER, JULIUS W., Chief Engineer M. & H. Zinc Co., La Salle, Ill.	Mar. 5, 1890
HEIDENREICH, EYVIND LEE, Contracting Engineer, 541 The Rookery, Chicago.	May 4, 1886
HEILBRONN, EMIL HENRY, Sub-Asst. Engr. Sanitary District of Chicago, 1516 So. Harding Ave., Chicago.	Mar. 7, 1900
HELLENTHAL, KARL, Bridge Engineer, C. L. Strobel, 1743 Monadnock Block, Chicago.	Mar. 11, 1899
HENDERSON, LIGHTNER, Purdy & Henderson, Civil Engineers, 78 Fifth Ave., New York.	Sept. 28, 1891
HERING, RUDOLPH, Hydraulic and Sanitary Engineer, 100 William St., New York City.	June 1, 1886
HERR, EDWIN M., Gen'l Manager Westinghouse Air Brake Co., Wilmerding, Pa.	July 7, 1896
HERR, HIERO B., *(Past-President)*, Civil and Mining Engineer, 5006 Washington Ave., Chicago.	June 16, 1885
HILL, FRED LEHMAN, Hill & Grant, Civil Engineers, 1640 Unity Bldg., Chicago.	Oct. 28, 1899
HILL, CICERO D., Chief Engineer Bureau Sewers, 207 City Hall, Chicago.	April 2, 1890
HILLEBRAND, GERHARD H., Chief Draftsman Sanitary District, 1005 Security Bldg., Chicago.	Mar. 1, 1898
HITZ, IRVING, Asst. Engineer B. & B. Dept., C. M. & St. P. Ry., 1100 Old Colony Bldg., Chicago.	Dec. 21, 1892
HOFF, JOHN HAKON, Hoff Bros., Engineers and Contractors, 1341 Marquette Bldg., Chicago.	July, 1, 1899
HOFFMAN, FRED, City Civil Engineer, Crawfordsville, Ind.	Mar. 11, 1899
HOGAN, WILLIAM F., Street Ry. Construction, 643 Tenth St., Brooklyn, N. Y.	April 8, 1891
HONENS, FREDERICK W., Inspector on Illinois and Mississippi Canal, Sterling, Ill.	July 1, 1899

NAME	ELECTED.
HORTON, GEORGE TERRY, Vice-President Chicago Bridge & Iron Co., Washington Heights Station, Chicago.	Nov. 7, 1894
HORTON, HORACE E., (*Past-President*) Pres. Chicago Bridge and Iron Co., Washington Heights Station, Chicago.	June 7, 1881
HOSKINS, WILLIAM, Chemist, Rooms 51-55, 81 So. Clark St., Chicago.	Sept. 4, 1889
HOTCHKISS, CHARLES W., Chief Engineer Chicago Junction Ry. Co., Monadnock Block, Chicago.	Jan. 2, 1895
HOTCHKISS, WILLIAM D., Asst. Engineer Bureau of Sewers, 207 City Hall, Chicago.	June 1, 1886
HOWELLS, J. M., Consulting Engineer, San Diego, Cal.	June 16, 1885
HUDSON, C. H., Consulting Engineer, 1021 Circle Park, Knoxville, Tenn.	Nov. 14, 1876
HUGHES, WILLIAM MCKENZIE, Consulting Bridge Engineer, 1511 Great Northern Bldg., Chicago.	Dec. 21, 1892
HULL, JULIAN SWITZER, Civil Engineer, 5443 Drexel Ave., Chicago.	June 5, 1896
HUNT, ROBERT W., (*Past-President*), Robert W. Hunt & Co., 1121 The Rookery, Chicago.	June 3, 1891
HURD, CHARLES HENRY, With R. W. Hunt & Co., 1121 The Rookery, Chicago.	Jan. 2, 1900
ILLSLEY, WILLIAM A., 215 Dearborn St., Room 1106, Chicago.	June 15, 1891
JACKSON, DUGALD C., Consulting Engineer and Prof. of Electrical Engineering, University of Wisconsin, Madison, Wis.	Feb. 4, 1891
JENISON, EDWARD SPENCER, C. E. & M. E., Hydraulic Engineer, 4356 Ellis Ave., Chicago.	July 6, 1897
JOHNSON, EDWARD E., Consulting Engineer, 605 First National Bank Bldg., Chicago.	Dec. 5, 1894
JOHNSON, GUSTAVUS J., Chemist Raymond Lead Co., 59 W. Lake St., Chicago.	Asso. Jan. 1, 1899 Act. M. Mar. 21, 1900
JOHNSON, JOHN BUTLER, Dean College of Mechanics aud Engineering, University of Wisconsin, Madison, Wis.	Mar. 11, 1899
JOHNSON, LORENZO M., Gen. Mgr. Mexican International Ry., P. O. Box 109, Eagle Pass, Tex.	Mar. 7, 1876
JOHNSTON, THOMAS T., (*Past-President*), Consulting Engineer Sanitary Dist. of Chicago, 1010 Security Bldg., Chicago.	Jan. 4, 1887
KANDELER, THEODORE, Bridge Engineer, 1616 Monadnock Block, Chicago.	Aug. 22, 1890
KARNER, WILLIAM J., Office Chief Engineer I. C. R. R., 1 Park Row, Chicago.	Mar. 5, 1890
KATTE, WALTER, Consulting Engineer, care E. B. Katte, Room 517 N. Y. C. R. R. Of., New York City.	July 12, 1869
KEATING, WILLIAM T., Asst. Eng. Sanitary District of Chicago, 1010 Security Bldg., Chicago.	Dec. 3, 1895
KELLER, CHARLES LINCOLN, The Scherzer Rolling Lift Bridge Co., 1616 Monadnock Block, Chicago.	Jan. 28, 1899
KELLOGG, FRANK PRESTON, Structural Engineer, 2449 Indiana Ave., Chicago.	Oct. 3, 1894
KELLY, JOSEPH I., Civil Engineer, Arizona Hydraulic Mining Co., Santa Cruz Co., Arizona.	Feb. 3, 1892

NAME	ELECTED
KERR, CHARLES VOLNEY, Professor Mechanical Engineering Armour Institute Technology, Chicago.	Jan. 11, 1897
KIMBALL, GRANVILLE, Mgr. Springfield Boiler & Mfg. Co. and Barr Pumping Engine Co., 1236 Marquette Bldg., Chicago.	Dec. 21, 1892
KLOSSOWSKI, THEODORE JULIUS, Draftsman U. S. Deep Waterway Board of Engineers, 34 Congress St., Detroit, Mich.	Junior Jan. 1, 1899 Act. M. Mar. 7, 1900
KRAMER, WILLIAM, Topographer Sanitary Dist., 1005 Security Bldg, Chicago.	Mar. 1, 1898
LAMONT, ROBERT P., V.-Pres. Simplex Ry. Appliance Co., Fisher Bldg., Chicago.	Oct. 3, 1894
LARY, JOHN HENRY, Chief Engineer D. & N. W. Ry., Nevada, Ia.	July 5, 1893
LASSIG, MORITZ, 1784 Deming Court, Chicago.	Oct. 4, 1887
LAWTON, DANIEL HERBERT, D. H. Lawton Co., 1200 Fisher Bldg., Chicago.	Nov. 7, 1894
LEDERLE, GEORGE ANTHONY, Civil Engineer and Contractor, Christie & Lowe, 171 La Salle St., Chicago.	Jan. 2, 1895
LEE, EDWARD H., Engineer and General Roadmaster C. & W. I. R. R. Co. and The Belt Ry. of Chicago, 45 Dearborn Station, Chicago.	Nov. 7, 1889
LEE, JOHN HENRY SHELDON, Attorney-at-Law, 525 Home Insurance Bldg., Chicago.	Oct. 28, 1900
LEE, WILLIAM, Civil Engineer, 201 Watt Ave., Pullman, Chicago.	April 2, 1890
LEWIS, JAMES ALLEN, Engineer for C. Everett Clark, Room 1015, 100 Washington St., Chicago.	Dec. 21, 1892
LEWIS, JAMES F., President Canadian Rand Drill Co., Sherbrooke, Quebec, Canada.	Nov. 1, 1893
LILJENCRANTZ, G. A. M., U. S. Asst. Engineer, 1637 Indiana Ave., Chicago.	Jan. 18, 1878
LINDAY, GEO. N., Designing Bridge Engineer, 1323 Monadnock Bldg., Chicago.	July 1, 1899
LONG, JAMES C., U. S. Asst. Engineer, U. S. Engineer's Office, Princeton. Ill.	Sept. 7, 1895
LOTTER, HENRY HOWELL, Instrumentman, c. o. U. S. Isthmian Canal Commission, Washington, D. C.	Junior Jan. 1, 1899 Act. M. Mar. 7, 1900
LOVE, WILLIAM D., Manager Chicago Office Wheeler Condenser & Engineering Co., 1642 Monadnock Block, Chicago.	Sept. 9, 1899
LOWE, JESSE, Christie, Lowe & Heyworth, Civil Engineers and Contractors, 171 La Salle St., Chicago.	Jan. 2, 1895
LYDON, WILLIAM A., Pres. Lydon & Drews Co., Dredging Contractors, 1321—23 Chamber of Commerce, Chicago.	Sept. 6, 1887
LYONS, JAMES KNOX, Chief of Dftg. Dept. Keystone Bridge Works, Pittsburgh, Pa.	Mar. 6, 1889
MACDONALD, DAVID, Draughtsman, 124 Northland Ave., Buffalo, N.Y.	Mar. 1, 1898
MACDONALD, FRED. A., Civil Engineer, Greensboro, N. C.	Feb. 3, 1892
MACDONALD, A. JAMES, Pres. Macdonald Engineering Co., 1454 Monadnock Block, Chicago.	Sept. 28, 1891
MACRITCHIE, CHARLES, Civil Engineer and Contractor, 21 Quincy St., Chicago.	Feb. 5, 1878
MADDOCK, HENRY S., Traveling Auditor C. & N. W. Ry. Co., 1027 Chicago Ave., Evanston, Ill.	Sept. 5, 1888

NAME	ELECTED
MAHER, DANIEL WILLIAM, Asst. Engineer Bureau of Street Engineers, 217 City Hall, Chicago.	June 5, 1889
MALLETTE, JAMES P., Eggleston & Mallette, 309 Tacoma Bldg., Chicago.	Mar. 3, 1891
MALONEY, JAMES EDWARD, 92 Park Place, Brooklyn, N. Y.	May 3, 1893
MANN, LOUIS M., U. S. Asst. Engineer, Local Charge Fox River Improvement, U. S. Engineer Office, Oshkosh, Wis.	Dec. 3, 1889
MARSHALL, WALDO H., Supt. Motive Power L. S. & M. S. Ry., Cleveland, Ohio.	Nov. 5, 1895
MARSTON, ANSON, Prof. Civil Engineering Iowa State College, Ames, Iowa.	July 1, 1899
MARX, CHARLES DAVID, Professor of Civil Engineering Leland Stanford University, Consulting Engineer, Stanford University, P. O., Cal.	Oct. 24, 1890
MAURY, DABNEY HERNDON, Consulting Engineer, Engineer Peoria Water Works Co., 129 N. Jefferson Ave., Peoria, Ill.	June 2, 1896
MAY, EMIL K., 1454 Monadnock Block, Chicago.	Junior Mar. 1 1898 Act. M. June 5, 1900
McCARTNEY, WILLIAM MAXWELL, Civil Engineer, care of Engineering Dept. Sanitary Dist. of Chicago, Chicago.	May 24, 1897
McCLOY, WILLIAM, Div. Engineer C. O. & G. R. R., Little Rock, Ark.	May 13, 1899
McFARLIN, WILLIAM KIRK, Chief Engineer D. L. & W. R. Ry., Hoboken, N. J.	July 1, 1899
McKINNON, JOHN B., Mechanical Engineer, Buda Fdy. & Mfg. Co., 917 Monadnock Block, Chicago.	June 15, 1891
McVEAN, JOHN JAY, Civil Engineer, 71 State St., Grand Rapids, Mich.	Oct. 3, 1882
MEAD, DANIEL WEBSTER, Consulting Engineer, 605 First National Bank Bldg., Chicago.	Mar. 1, 1887
MEADOWS, H. H. Mgr. Southeastern office Babcock & Wilcox Co. (New York) 817 Equitable Bldg., Atlanta, Ga.	Junior, Mar. 2, 1897 Active Mem., Feb. 1, 1898
MELCHER, CHARLES WOODBURY, Western Manager Ingersoll-Sergeant Drill Co. 84 Van Buren St., Old Colony Bldg., Chicago.	Nov. 5, 1895
MERRIAM, LAUREN BRONSON Resident Engineer U. P. R. R., Laramie, Wyo.	Mar. 5, 1895
METCALF, JOHN S., Pres. John S. Metcalf & Co., Grain Elevator Builders, 1075 W. 15th St., Chicago.	Sept. 28, 1891
MILLER, E. D. Civil Engineer, 1831 Arlington Place, Chicago.	Dec. 21, 1892
MILLER, HIRAM ALLEN, Engineer Reservoir Department Metropolitan Water Board 124 Walnut St., Clinton, Mass.	June 7, 1893
MILTIMORE, GUY, Asst. Engineer Intercepting Sewers, 207 City Hall, Chicago.	Jan. 28, 1899
MODJESKI, RALPH. (*Treasurer*), Consulting Civil Engineer, 1742 Monadnock Block, Chicago.	Dec. 7, 1892
MOHR, LOUIS, Consulting Engineer and Secretary of John Mohr & Sons, 32 Illinois St., Chicago.	Aug. 3, 1886
MORGAN, DWIGHT CADOGAN, Civil Engineer and Railway Expert, Richard P. Morgan & Son, Dwight, Ill.	Dec 30, 1890
MORGAN, RICHARD PRICE, Civil Engineer and Railway Expert, Dwight, Ill.	Jan. 4, 1887
MORISON, GEORGE SHATTUCK, Civil Engineer, 35 Wall St., New York City.	Oct. 9, 1879
MORSE, CHARLES JAMES, 1825 Asbury Ave., Evanston, Ill.	Sept 26, 1890

NAME	ELECTED
MOTH, ROBERT H., City Engineer and Supt. of Water Works, Kenosha, Wis.	June 5, 1900
MOTT, ARTHUR D., Ritter & Mott, Civil Engineers, 1336 Marquette Bldg., Chicago. Not a member from 1893 to 1898.	April 19, 1892
MURPHY, EDWARD JOSEPH, With John Lundie, Consulting Engineer, Room 926, 52 Broadway, New York.	June 2, 1896
NICHOL, JOHN, 21 Quincy St., Chicago.	Mar. 7, 1876
NICHOLL, T. J. Vice-Pres. Rochester Ry. Co., 267 State, Rochester, N. Y.	Sept. 10, 1872
NICHOLS, GEORGE PERRY, (*Trustee*), G. P. Nichols & Bro., Engineers and Contractors, 1325 Monadnock Block, Chicago.	Nov. 7, 1894
NICHOLS, LEWIS A. President Nichols Engineering & Contracting Co., 1538 Monadnock Block, Chicago.	Oct. 28, 1899
NICHOLS SAMUEL FRENCH, G. P. Nichols & Bro. Coal Mining, Hoisting and Conveying Machinery, 1325 Monadnock Block, Chicago.	Feb. 25, 1896
NOBLE ALFRED, (*Past-President*), Member U. S. Board of Engineers on Deep Waterways and Isthmian Canal Commission, 1742 Monadnock Block, Chicago.	Dec. 20, 1893
OLMSTED, L. S. General Engineering, Drainage and Bridging, Jacksonville, Ill.	Feb. 2, 1875
ORR, ROBERT E. Asst. Enginneer C. J & E. Ry., City Engineer East Chicago, Ind., 200 Eastern Ave., So, Joliet, Ill.	April 6, 1892
OSTENFELDT, CHARLES L. 23d Place and Archer Ave., Chicago.	Dec. 2, 1889
OSTROM, JOHN NELSON, Bridge Engineer, 185 44th St., Pittsburgh, Pa.	May 4, 1886
PAGE, JOHN WILLIAM. With Gahan & Byrne, Joliet, Ill.	Mar. 1, 1898
PAIGE, A. W. 45 Washington Ave., Schenactady, N. Y.	Dec. 13, 1869
PARKER, WILLIAM AUGUSTUS, Resident Engineer Union Pac. R. R., Junction City, Kan.	Feb. 3, 1892
PARADIS, FREDERICK EDWARD, Chief Engineer Chicago Terminal Trans. R. R., 353 Grand Central Passenger Station, Chicago.	Jan. 11, 1897
PARKHURST, HENRY WILLIAMS, Engineer of Bridges and Buildings, Illinois Central R. R., 1 Park Row, Chicago.	Jan. 7, 1879
PARVIN, THEODORE WARREN, Chief Engineer Ferro-Carril "Potosi y Rio Verde," San Luis Potosi, Mexico.	May 6, 1891
PENCE, WILLIAM DAVID, Prof. Civil Engineering Purdue University, LaFayette, Ind.	Jan. 4, 1893
PICKELS, WILLIAM D. Mgr. Chicago Warren Webster & Co., 1510 Monadnock Block, Chicago.	April 30, 1895
PORTER, HOLBROOK FITZ JOHN, Sales Agent Bethlehem Steel Co., So. Bethlehem, Pa.	Jan. 2, 1895
PORTER, HENRY H., (mark *Personal*) 71 Broadway, New York City.	June 1, 1886
POTTER, WILLIAM GRAY, Chief Asst. Engineer Alvord & Shields, 127 Hartford Bldg. Chicago.	Feb. 4, 1891
POUND, NICHOLAS D., Pound Construction Co., 27 Metropolitan Block, Chicago.	April 2, 1895
POWELL, AMBROSE VINCENT, (*President*), Civil Engineer, 1008 Chamber of Commerce, Chicago.	April 5, 1881

NAME	ELECTED
PRATT, WILLIAM HENRY, ... Manager Structural Dept. Illinois Steel Co. 50 Wabansia Ave., Chicago.	June 5, 1899
PRELL, JOHN STILLMAN . . . . Civil and Mech. Engineer, 615 Eddy St., San Francisco, Cal.	Feb. 1, 1898
PRICE, WILLIAM GUNN, ... Engineer and General Superintendent Peckham Truck Co., Kingston, N. Y.	Jan. 11, 1897
PRIOR, JOSEPH HENRY, ... Bridge Draftsman C. M. & St.P. Ry., 1100 Old Colony Bldg., Chicago.	Oct. 20, 1898
PURDY, CORYDON T. . . . . Purdy & Henderson, Civil Engineers, 78 Fifth Ave ew York City.	Sept. 4, 1889
RANDOLPH, HENRY ISHAM . . . . Riverside, Ill.	Mar. 7, 1900
RANDOLPH. ISHAM, (*Past President*), ... Chief Engineer, Sanitary District of Chicago, 1010 Security Bldg., Chicago.	April 5, 1881
RANSOME, ERNEST LESLIE, ... Concrete Specialist, Singer Bldg., 149 Broadway, New York City.	Nov. 7, 1894
REDMAN, CHARLES HERBERT. . . . . . Chief Engineer's Office, Grand Rapids, Mich.	July 3, 1899
REECE, BENJAMIN, ... Engineer Diamond Iron Co., Real Estate Bldg., Philadelphia, Pa.	Mar. 4, 1879
REICHMANN, ALBERT, ... Assistant Engineer C. M. & St. P. Ry., 1100 Old Colony Bldg., Chicago.	Dec. 10, 1897
REYNOLDS, JAMES J., ... Civil Engineer, 421 45th St,, Chicago.	June 2, 1890
RICHTER, PAUL K., ... Prest. American Bridge Works, 40th St. and Stewart Ave., Chicago.	April 3, 1888
RIPLEY, JOSEPH. . . . . U. S. Asst. Engineer and Genl. Supt. St. Mary's Falls Canal, Sault Ste. Marie, Mich.	Aug. 6, 1896
ROBERTS, CHARLES N., ... Engineer and Surveyor, 709-711 Reaper Block, Chicago.	April 6, 1892
ROBERTS, WARREN R., ... Civil Engineer, 1440 Marquette Bldg., Chicago.	Dec. 30, 1890
ROBINSON, EUGENE M., ... Asst. Engineer, C. & N. W. Ry., 22 Fifth Ave., Chicago.	Nov. 7, 1894
ROBINSON, JAMES S., ... Division Engineer C. &. N. W. Ry., No. 1 W. Kinzie St Chicago.	Feb. 3, 1892
ROEMHELD, J. E. . . . . Roemheld & Gallery, 802, 91 Dearborn St., Chicago. Not a member in 1893-4-5.	1892
ROGERS, Walter A., ... Engineer of Permanent Construction, Bridge and Building Dept., C. M. & St. P. Ry., 1100 Old Colony Bldg., Chicago.	Oct 20, 1898
ROHRER, JACOB BOMBERGER, ... Asst. Chief Engr. H. R. T. & L. Co., Honolulu, Hawaiian Islands.	May 2, 1894
ROSENCRANS, EDWIN J. . . . . Member firm of Green & Wicks, 110 Franklin St,. Buffalo, N. Y.	Oct. 20, 1898
ROWE, SAMUEL M., ... Consulting Engineer Timber Preservation, Room 802, 226 LaSalle St., Chicago.	Feb. 3, 1892
ROYSE, DANIEL, ... Mechanical Editor, St. Ry. Review, 1310 Monon Bldg., 324 Dearborn St., Chicago.	Mar. 24, 1897
RUDIGER, EUGENE ADOLPHUS . . . . . . Civil Engineer and Contractor, Peekskill, N. Y.	June 5, 1889
RUST, HENRY A., ... Cobb Hall, Comptroller University of Chicago.	Nov. 6, 1877

NAME	ELECTED
RUTLEDGE, ARTHUR E., A. E. Rutledge & Co., Rockford, Ill.	Mar. 7, 1894
RYLAND SAMUEL V., Operating Gold and Silver Mines, Stockton, Cal.	June 2, 1890
SAGER, NELSON ALBERT, Chief Engineer Intercepting Sewer, Division 207, City Hall, Chicago.	Jan. 28, 1899
SALMON, WILMER WESLEY, 2nd Vice-President Hall Signal Co., 1423 Monadnock Block, Chicago.	Feb. 3, 1892
SALTAR, JOHN, JR., Vice-President and Engineer of the Otto Gas Engine Works, 33d and Walnut Sts., Philadelphia, Pa.	Oct. 7, 1884
SANBORN, WILLIS REMSEN, Division Engineer I. I. & I. R.R., Granville, Putnam Co., Ill.	Mar. 21, 1900
SANNE, OSCAR, Assistant Engineer Manhattan Ry. Co., 32 Park Place, New York.	Mar. 1, 1898
SARGENT, FITZWILLIAM, Chief Engineer The Sargent Co.,675 Old Colony Bldg.,Chicago.	June 5, 1899
SARGENT FREDERICK, Sargent & Lundy, 1140 Monadnock Block, Chicago.	Mar. 1, 1897
SARGENT WILLIAM D., Vice-Pres., and Genl. Manager The Sargent Co., 675 Old Colony Bldg., Chicago.	Dec. 1, 1896
SCHENCK, ARCHIBALD ALEXANDER, Division Engineer C. & N. W. Ry., Boone, Iowa.	July 1, 1899
SCHNIGLAU, CHARLES R., Vice-Pres. Shailer & Schniglau Co., 611 Western Union Bldg., Chicago.	Mar. 5, 1890
SCHRADER, A. C. Engineer West Chicago Park Commissioners, Union Park, Chicago. Not a member in 1894-5.	Mar. 4, 1891
SEDDON, JAMES A. 1637 Indiana Ave., Chicago.	Mar. 7, 1900
SEWALL, JOSEPH S., Bridge and General City Work, St. Anthony Park, Minn.	May 7, 1878
SEYMOUR, ROBERT B., Asst. Engineer M. C. R. R. Co., Room 620, 218 LaSalle St., Chicago.	Dec. 30, 1890
SEYMOUR, RUDGELEY D., Wire Rope Transportation, 1114 Monadnock Block, Chicago.	Jan. 11, 1897
SHAILER. ROBERT AMES, Pres. Shailer & Schniglau Co., Engineers and Contractors, Western Union Bldg., Chicago.	Mar. 6, 1888
SHANKLAND, EDWARD CLAPP, E. C. & R. M. Shankland, 816, The Rookery, Chicago.	Asso. July 5, 1881; Mem. Oct. 4, 1887
SHANKLAND, RALPH M., E. C. & R. M. Shankland, 816, The Rookery, Chicago. Not a member in 1894-5-6-7-8.	May 7, 1890
SHELDON, ADELBERT, With The Fort Pitt Bridge Co., Cannonsburg, Pa.	Jan. 3, 1899
SHERMAN, LEROY KEMPTON, Civil Engineer Sanitary District of Chicago, Lockport, Ill.	Dec. 3, 1895
SHIELDS, WILLIAM S., Alvord & Shields, Civil, Sanitary and Hydraulic Engineers, 127 Hartford Bldg., Chicago.	July 31, 1899
SHNABLE, EMIL R. Engineer and Contractor, 2371 N. Paulina St., Chicago.	Feb. 4, 1891
SIMONDS, OSSIAN C., Landscape Gardener, Buena Ave., Chicago.	Aug. 3, 1886
SLIPER, HIRAM L., Supt. C. & N. W. Ry., Boone, Iowa.	Sept. 7, 1897
SLOAN, DAVID, Chief Engineer I. C. R. R., No. 1 Park Row, Chicago.	Mar. 1, 1898
SMITH, WILLARD A., President The Cloud Steel Truck Co., 1425 Old Colony Bldg., Chicago.	Feb. 4, 1891

NAME — ELECTED

SMITH, WILLIAM PENN. . . . . Mar. 11, 1899
Civil Engineer, 1017 Monadnock Block, Chicago.

SMITH, GEN. WILLIAM SOOY, (*Past President*), . . Oct. 8, 1874
733-734 Chicago Stock Exchange Bldg., Chicago.

SNOW, THEODORE WILBUR, ... { Asso. Dec. 5, 1894 / Mem. Mar. 17, 1896 }
Manager Otto Gas Engine Works, 360 Dearborn St., Chicago.

SNYDER, CHRISTOPHER HENRY, ... Oct. 20, 1894
Asst. to Chief Engineer, 11 Broadway, New York City.

SOOYSMITH, CHARLES, ... Mar. 6, 1877
Consulting Engineer, 71 Broadway, New York City.

SORGE, ADOLPH, JR., ... May 2, 1900
Mechanical Engineer A. Sorge Jr. & Co., 1019-1021 Monadnock Block, Chicago,

SPAAK CHARLES ERIC, ... July 11, 1888
Engineer Ind. Nat. Gas & Oil Co., 14 E. Monroe St., Chicago.

SPENGLER, JOHN HENRY, ... June 2, 1890
Asst. City Engineer, 325 City Hall, Chicago.

SPERRY, HENRY MUHLENBERG, ... Feb. 3, 1892
Signal Engineer and Agt., The Union Switch and Signal Co., 26 Cortlandt St., New York City.

SPICER, V. K. . . . . Feb. 3, 1892
Signal Engineer and Agt., The Union Switch and Signal Co., 1535 Monadnock Block, Chicago.

SPRINGER GEO. B., ... Dec. 5, 1890
Civil Engineer Chicago Edison Co., 139 Adams St., Chicago.
Not a member in 1893-4-5.

STEARNS, WILLIAM HENRY, ... Jan. 2, 1895
248 Home Ave., Oak Park, Ill.

STEBBINGS, WALTER LOUIS, ... Jan. 6, 1890
Civil and Consulting Engineer, 1111-1113 Monadnock Block, Chicago.

STEPHENS, JAMES S., ... July 7, 1896
Pres. Stephen's Engineering Co., The Rookery, Chicago.

STEVENS, HUBERT A., ... Mar. 1, 1887
City Engr.'s Office, Joliet, Ill.

STEWART, CLINTON BROWN, ... Oct. 24, 1890
Asst. Engineer U. S. Board of Engineers, 34 W. Congress St., Detroit, Mich.

STICKNEY, SAMUEL CROSBY, ... Oct. 24, 1890
Gen'l Manager Chicago Great Western Ry., St. Paul, Minn.

STOWELL, CHARLES C., ... Mar. 1, 1893
Municipal Engineer, 228 N. 4th St., Rockford, Ill.

STRAUSS JOSEPH BAERMAN, ... Dec. 8, 1899
BridgeEngineer, 1742 Monadnock Block, Chicago.

STROBEL, CHARLES LEWIS, ... Mar. 2, 1886
Consulting and Contracting Engineer, 1744-8 Monadnock Block, Chicago.

STUCKER, NOAH E., ... Oct. 5, 1892
Engineer and Contractor, Ottawa, Ill.

SUMMERS, LELAND L., ... Dec. 3, 1895
Consulting Engineer, 441 The Rookery, Chicago.

TALBOT, ARTHUR N., ... July 5, 1887
Prof. of Municipal and Sanitary Engineering, University of Illinois, Urbana, Ill.

TARBET, WILLIAM L., ... Jan. 28, 1899
Tax Commissioner I. C. R. R., No. 1 Park Row, Chicago.

THOMAS, BENJAMIN, ... May 6, 1891
Pres. and Gen'l Manager C. & W. I. R. R. Co., Room 11, Dearborn Station, Chicago.

THOMAS, GEORGE EDWARD, ... Aug. 1, 1894
Supt. Engineering Contract Co., 71 Broadway, New York City.

THOMAS, MARION ELLIS . . . . . . { Junior Feb. 25, 1898 / Active Mem. Mar. 7, 1900 }
Sanborn, Minn., Asst. Eng. C. & N. W. Ry.

THOMPSON, ALMON D., ... Jan. 7, 1894
City Engineer, Peoria, Ill.

NAME	ELECTED
THOMPSON, HUGH PERRONET, 445 W. 46th St., Chicago.	Nov. 9, 1889
THROOP, WILLIAM B., Div. Supt. C. B. & Q. R. R., Galesburg. Ill.	May 4, 1886
TORREY, AUGUSTUS, Chief Engineer M. C. R. R., Detroit, Mich.	Mar. 17, 1896
TOWLER, MAXIMILIAN JOSEPH LOUIS, General Superintendent Detroit Bridge and Iron Works, Detroit, Mich.	July 10, 1889
TRATMAN, EDWARD ERNEST RUSSELL, Resident Editor Engineering News, 1636 Monadnock Block, Chicago.	July 1, 1899
TRUEMAN, HARMON, Chief Engineer Morden Frog & Crossing Wks., 818 The Rookery, Chicago.	Jan. 19, 1897
TULLOCK, ALONZO J., Proprietor Mo. Valley Bridge and Iron Works, Leavenworth, Kan.	Nov. 6, 1877
TURNEAURE, FREDERICK E., Prof. Bridge and Sanitary Engineering University of Wisconsin, Madison, Wis.	Jan. 11, 1897
TUTTON, CHARLES H., Engineer for Gratton & Jennings, Contractors, Foot of Main St., Buffalo, N. Y.	Dec. 4, 1877
VANDERLIP, HENRY E., Civil Engineer Geo. B. Swift Co., General Contractors. 903 Security Bldg., Chicago.	May 4, 1897
VIAL, FREDERICK, K., Asst. Engineer C. & W.I.R.R., 45 Dearborn Station, Chicago.	Jan. 3, 1899
VOGELSBERGER. GUSTAV, Civil Engineer, care of Geo. A. Fuller Co., 135 Broadway, New York City.	July 7, 1897
WADE, CHARLES G., Mechanical Engineer, Room 1200, 228 La Salle St., Chicago, Ill.	Sept. 4, 1889
WAGNER, RICHARD G., Manager Milwaukee Bridge and Iron Works, Milwaukee, Wis.	Dec. 1, 1897
WALKER. JOHN, Mechanical Engineer, Gurnee, Lake Co., Ill.	Jan. 11, 1897
WALLACE, JOHN FINDLEY, (*Past-President*), Asst. 2nd Vice-Pres. Illinois Cent. R. R. Co., Central Station, Chicago.	June 5, 1889
WALLACE, WILLIAM A., Asst. Engineer C. I. & L. Ry. Co., 198 Custom House Place, Chicago.	April 19, 1898
WARDER, JOHN H., Asst. Engineer Bureau of Sewers, 207 City Hall, Chicago.	Oct. 20, 1898
WASHBURN, FRANK S., Cole Bldg., Nashville, Tenn.	Jan. 8, 1884
WEBSTER, HOSEA, Mechanical Engineer, 29 Cortlandt St.. New York City.	Nov. 1, 1889
WESTCOTT, OLIVER JOHNSON, Engineer Struct. Dept. Ill. Steel Co., 50 Wabansia Ave., Chicago.	Dec. 1, 1892
WESTON, CHARLES VALENTINE, Chief Engineer Northwestern Elevated R. R. Co., Lake St. Elevated R. R. and Union Elevated R. R. Co., 444 N. Clark St., Chicago.	Sept. 26, 1890
WESTON, GEORGE, Engineer Construction Dept., Naugle, Holcomb & Co., 355 Dearborn St., Chicago.	April 6, 1892
WESTON, JOHN W., Publisher, Blue Island, Ill.	Jan. 2, 1877
WHITLEY, NOAH, Civil Engineer, Court House, Joliet, Ill. Not a member in 1894-5-6 and '97.	Nov. 5, 1890

NAME	ELECTED
WHITNEY, PROF. NELSON OLIVER, Civil Engineer, Prof. of Railway Engineering, University of Wisconsin, Madison, Wis,	April 8, 1891
WHITTEMORE, DON JUAN, Chief Engineer C. M. & St. Paul Ry., 1100 Old Colony Building, Chicago.	April 8, 1872
WHITRIDGE, JOHN CLIFFORD, Associate Editor Railroad Gazette, 1750 Monadnock Block, Chicago.	Jun. Mar. 2, 1897 Mem. Oct. 1, 1898
WILKINS, GEORGE SHREVE, In charge Collecting Exhibit of American Engineering for the Paris Exposition of 1900, Auditorium Bldg., Chicago.	July 3, 1899
WILLIAMS, BENEZETTE, (*Past-President*), Civil Engineer and Contractor, 801 Association Building, 153 La Salle St., Chicago.	Oct. 14, 1872
WILLIAMS, HERBERT EVAN, 1522 Monadnock Block, Chicago.	Jan. 11, 1897
WILLIAMS, WILLIAM ERASTUS, Civil and Mechanical Engineer, 1001 Monadnock Block, Chicago.	Dec. 4, 1889
WILLIAMSON, JOHN, Consulting Engineer, People's Gas Light & Coke Co., 157 Michigan Ave., Chicago.	Sept. 7, 1897
WILLIS, PAUL, Sec'y and Engineer, Kenwood Bridge Co., 617 First National Bank, Chicago.	Dec. 30, 1890
WILLS, EDWARD SMITH, Supt. Atchison Water Co., Atchison, Kan.	Sept. 28, 1891
WILMANN, EDWARD, City Bridge Engineer, Room 327 City Hall, Chicago.	July 11, 1894
WINDETT, VICTOR, Civil Engineer South Works, Illinois Steel Co., Chicago.	Jan. 4, 1893
WINSTON, WILLIAM OVERTON, Winston Bros., Contractors, Bank of Commerce Bldg. Minneapolis, Minn.	Sept. 2, 1884
WISNER, GEORGE MONROE, Asst. Engineer Sanitary District, 1010 Security Bldg., Chicago.	Mar. 17, 1896
WISNER, GEORGE Y., Civil and Consulting Engineer, 39 Canfield Ave., W. Detroit, Mich.	Jan. 3, 1899
WITHERSPOON, JOHN MCCALLA, Supt. G. M. Moulton & Co., 1811 Fisher Bldg., Chicago.	Dec. 5, 1894
WOLF, ALBERT H., Consulting and Contracting Engineer Structural Steel Work for Buildings and Bridges, 720-2, 218 La Salle St., Chicago.	Dec. 30, 1890
WOLHAUPTER, BENJ., 6426 Kimbark Ave., Chicago.	Dec. 30, 1890
WORDEN, BEVERLY L., Bridge Engineer, care Wisconsin Bridge & Iron Co., 706 Pabst Bldg., Milwaukee, Wis.	Jan. 11, 1897
WRIGHT, AUGUSTINE W., (*Past-President*), Consulting Engineer, Pomona, Cal.	May 6, 1879
YODER, WILLIAM JACKSON, Resident Engineer Balt. & Ohio R. R., Tiffin, Ohio.	Mar. 1, 1887
ZIESING, AUGUST (*Trustee*), Consulting Civil Engineer, 1323-4 Monadnock Block, Chicago.	June 5, 1889
ZURCHER, MAX A., Bridge Engineer, Chief Engineer's Office, Canadian Pacific Ry., Montreal, Canada.	Oct. 18, 1881

ACTIVE MEMBERS, 422.

ASSOCIATES.

(*Asso. M. W. S. E.*)

NAME	ELECTED
ALDERSON, VICTOR C., Dean of the Technical College, Armour Institute of Technology, Thirty-third St. and Armour Ave., Chicago.	Oct. 28, 1899
ALLISON, JOHN T., Western Agent American Forcite Powder Co., 1007 Chamber of Commerce Bldg., Chicago.	Jan. 19, 1897
BOLDENWECK WILLIAM, Trustee Sanitary Dist. of Chicago, Security Bldg., Chicago.	Nov. 7, 1894
BRYANT, GEORGE HORACE, Rep. of Thos. Prosser & Son, 1405 Old Colony Bldg., Chicago.	April 2, 1895
BYRNE, THOMAS, Gahan & Byrne, General Contractors, 5502 Halsted St., Chicago.	Nov. 7, 1894
DICKINSON, JOHN W., Vice-Pres. Dickinson Cement Co., 931 Marquette Bldg., Chicago.	Jan. 4, 1898
DIETZGEN EUGENE, Prest. Eugene Dietzgen Co., 181 Monroe St., Chicago.	Sept. 7, 1886
ELLIS, JEROME A., General Mgr. National Ry. Spring Co., Dickson Locomotive Works, 707 Great Northern Bldg., Chicago.	Mar. 24, 1897
ESSON, JOHN H., Contractor Paving and Bridge Masonry, 1008 Chamber of Commerce Bldg., Chicago.	Jan. 19, 1897
GARDNER, JAMES W., Sales Agent, 675 Old Colony Bldg., Chicago.	Jan. 7, 1896
GRIFFITHS, JOHN, 40 Lakeside Bldg., Chicago.	Nov. 7, 1894
JOHNSON, FRANK JAMES, American Hoist & Derrick Co., 60 So. Canal St., Chicago.	Jan. 11, 1897
LINK, RUDOLPH, Manager Keuffel & Esser Co., 111 Madison St., Chicago.	Nov. 5, 1895
LITTEN, NELSON L., (*Secretary*), 1737 Monadnock Block, Chicago.	Jan. 11, 1897
MACOMBER, F. B., Sec'y-Treas. Leschen-Macomber-Whyte Co., 19 So. Canal St., Chicago.	Jan. 1, 1899
MCARTHUR, ARCHIBALD, McArthur Bros. Co., Contractors, 1410 Great Northern Bldg., Chicago.	Nov. 7, 1894
MCARTHUR, ARTHUR F., Treasurer McArthur Bros. Co., Chicago.	Mar. 2, 1897
MOORE, OLIN F., With Sears Humbert & Co., 34 Clark St., Chicago.	Mar. 11, 1899

NAME	ELECTED
PATERSON, JAMES S., Prest. J. S. Paterson Construction Co., 1330 Monadnock Block, Chicago.	Mar. 17, 1896
QUINCY, CHARLES F., Prest. and Treas. The Q. & C. Co., 700-711 Western Union Bldg., Chicago.	April 2, 1895
REYNOLDS, JOHN N., Western Representative Railroad Gazette, 1750 Monadnock Block, Chicago.	July 30, 1898
ROSS, ARTHUR J., 1205 Monadnock Block, Chicago.	Jan. 11, 1897
ROWLEY, SAM'L T., Western Agent of The Standard Railroad Signal Co. of Troy, N. Y., 1030 Monadnock Block, Chicago.	Jan. 3, 1899
SCHAUFFLER, CHARLES EDWARD, Resident Manager Empire Portland Cement Co., 737 Monadnock Block, Chicago.	Jan. 2, 1895
SCRIBNER, GILBERT H., JR., Vice-Pres. J. S. Paterson Construction Co., 1500 Wabash Ave., Chicago.	Mar. 17, 1896
SINCLAIR, DONALD, Sinclair Con. Co., Monadnock Block, Chicago.	Jan. 28, 1899
WILSON, HUGH M., Manager The Railway Age, Monadnock Block, Chicago.	Mar. 7, 1900
WINSTON, JAMES O., Winston & Co., General Contractors, 1410 Great Northern Bldg., Chicago.	Feb. 25, 1896

ASSOCIATES, 28.

JUNIORS.

(Junior M. W. S. E.)

NAME	ELECTED
ADAMS, EDWARD LANGFORD, The Sargent Co., 675 Old Colony Bldg., Chicago.	July 1, 1899
ANDERSON, GEORGE FORBES, Bridge Dept. I. C. R. R., R. 902, No. 1 Park Row, Chicago.	Jan. 1, 1899
BECKERLEG, GWAVAS FOSTER, With A. Ziesing, 1323 Monadnock Block, Chicago.	July 1, 1899
BECKMAN, BURCHARD FREDERICK, Asst. Roadmaster C. B. & Q. R. R., Ottumwa, Iowa.	Mar. 7, 1900
BOSWORTH, C. I., Levelman Engr. Dept. Oregon Short Line Ry., Pocatello, Idaho.	May 13, 1899
BRIGGS, JAMES, Asst. Engr. C. B. & Q. R. R., Burlington, Iowa.	Sept. 9, 1899
BROWNELL, J. DEMPSTER, Supt. Rose Hill Cemetry, Chicago.	July 1, 1899
BRUCE, WILLIAM ALMAN, Inspector for Pittsburg Testing Laboratory, Ltd., 1750 Monadnock Block, Chicago.	July 1, 1899
BUNNEL, W. C., U. S. Engineer's Office, Chicago.	June —, 1900
BUTTON, ERNEST D., Resident Engineer I. C. R. R., Lyle, Minn.	Sept. 9, 1899
CLAYTON, THOMAS WILEY, Inspector, 1323 Monadnock Block, Chicago.	July 3, 1899
CONGER, ALGER ADAMS, Instrumentman U. S. I. C., 109 Corcoran Bldg. Washington, D. C.	Jan. 3, 1899
CUMMINS, THOMAS RISDON, Asst. Engr. Illinois Central R. R., Freeport, Ill.	Mar. 21, 1899
CUNNINGHAM, EDWARD WALTER, Civil Engineer Shoenberger Works, A. S. & W. Co., Penn Ave. and 15th St., Pittsburg, Pa.	Nov. 28, 1899
DAKIN, HENRY, Asst. to City Engineer, R. 4, City Hall, Elgin. Ill.	May 2, 1900
DRAKE, CHARLES S., With C. & N. W. Ry., 22 Fifth Ave., Room 30, Chicago.	Jan. 1, 1899
DUNAWAY, ARTHUR N., 220 North 16th St., Mattoon, Ill.	Jan. 1, 1899
EVANS, EDWARD M., Shop Inspector, 1323 Monadnock Block, Chicago.	July 3, 1899
FITZPATRICK, P. DAN, Asst. Engr. I. C. R. R., R. 902, 1 Park Row, Chicago.	July 1, 1899
FLANDERS, LOUIS H., Instructor Mechanical Engineering, Armour Institute of Technology, Chicago.	Mar. 7, 1900
GERATY, GEORGE C., Civil Engineer, 5312 Jackson Ave., Chicago.	Mar. 1, 1898
GRADY, JOHN E., Instrumentman Sanitary Dist., 1008 Security Bldg., Chicago.	July 20, 1897
HADSALL, HARRY H., Asst. Engr. Bridge Dept. I. C. R. R., R. 902, 1 Park Row, Chicago.	Oct. 28, 1899
HILL, MERLE D., C. M. & St. P. Ry., Draftsman, 1100 Old Colony Bldg., Chicago.	Mar. 21, 1900
HUNT, WILSON PERCIVAL, Care Deere & Mansur Co. Moline, Ill.	Mar. 24, 1897
JAMES, BENJAMIN WINFIELD. Illinois Steel Co., Joliet, Ill.	July 3, 1899

NAME	ELECTED
KIRCHOFFER, WILLIAM GRAY, City Engineer Water Works Construction, Baraboo, Wis.	July 3, 1899
KNAPP, CHARLES SPECK, Mechanical Draftsman, 525 Pullman Bldg., Chicago.	Jan. 3, 1899
LOGEMANN, RICHARD T., Columbus, Wis.	July 31, 1899
MAXON, ROBBINS YALE, With Chief Engineer C. & E. R. R. Co., Chicago.	Sept. 7, 1897
MCDONALD, CLINTON, Asst. Engr. C. & N. W. R. R., Og den, Ia.	May 2, 1900
MONTGOMERY, JOHN BULL, Resident Manager The Roebling Construction Co., 171 Lake St., Chicago.	July 31, 1899
MUSHAM, JOHN WILLIAM, Bridge Draftsman C. M. & St. P. Ry., 1100 Old Colony Bldg., Chicago.	June 5, 1899
NORTH, WILLIAM HARRISON, Draftsman, Keystone Bridge Co., Pittsburgh, Pa.	Mar. 21, 1900
QUADE, JOHN C., Civil Engineer for Western Tube Co., Kewanee, Ill.	Jan. 11, 1897
ROCKWELL, JAMES VINCENT, Asst. Engineer C. & N. W. Ry., Ames, Iowa.	July 1, 1899
ROSS, HARRY HURSON, Division Engineer B. & M. R. R., Room 14 B. & M. R. R. Depot, Lincoln, Neb.	Jan. 11, 1897
SAFFORD, HARRY ROBINSON, Roadmaster I. C. R. R. Co., Clinton, Ill.	April 19, 1898
SCHAFER, OTTO, Transitman C. M. & St. P. Ry., 1100 Old Colony Bldg., Chicago.	Oct. 28, 1899
SLOAN, WILLIAM GRIFFITHS, Asst. Engineer I. C. R. R., Grenada, Miss.	July 1, 1899
SMITH, ROBERT COLFAX, With Isthmian Canal Commission, Washington, D. C.	Oct. 3, 1899
STEWART, MORTON BISHOP, Mechanical Draftsman, Missouri Edison Electric Co., 19th & Gratiot St., St. Louis, Mo.	Dec. 8, 1899
TENNY, MARK W., With U. S. Board of Engineers Deep Waterways, 34 Congress St., Detroit, Mich.	Jan. 1, 1899
TRUMBULL, MORRIS KINNARD, Asst. Engineer Fort Dodge & Omaha R. R., 1201 Avenue A, Council Bluffs, Iowa.	Jan. 1, 1899
VENT, FREDERICK GOODMAN, American Bridge Works, Chicago.	June 5, 1899
WARREN, ALEXANDER CLIFTON, Koeffer & Co., Concrete Construction, 315 Chamber of Commerce Bldg., Chicage.	Nov. 28, 1899

JUNIORS, 46.

RECAPITULATION.

Honorary Member	1
Active Members	422
Associates	28
Juniors	46
Total Membership to Date	497

Chicago, 21 June, 1900.

PAST AND PRESENT OFFICERS.

PRESIDENTS.

*ROSWELL B. MASON	June 14, 1869	to	June 13, 1870
CHARLES PAINE	June 13, 1870	to	June 9, 1873
*E. S. CHESBROUGH	June 9, 1873	to	June 19, 1877
WM. SOOY SMITH	June 19, 1877	to	Aug. 3, 1880
*E. S. CHESBROUGH	Aug. 3, 1880	to	Jan. 2, 1882
*WILLARD S. POPE	Jan. 2, 1882	to	Jan. 8, 1883
*DEWITT C. CREGIER	" 9, 1883	to	" 6, 1885
BENEZETTE WILLIAMS	" 6, 1885	to	" 5, 1886
AUGUSTINE W. WRIGHT	" 5, 1886	to	" 4, 1887
SAMUEL G. ARTINGSTALL	" 4, 1887	to	" 3, 1888
*A. GOTTLIEB	" 3, 1888	to	" 8, 1889
E. L. CORTHELL	" 8, 1889	to	" 8, 1890
L. E. COOLEY	" 8, 1890	to	Feb. 3, 1892
ISHAM RANDOLPH	Feb. 3, 1892	to	Jan. 4, 1893
ROBERT W. HUNT	Jan. 4, 1893	to	" 3, 1894
HIERO B. HERR	" 3, 1894	to	" 2, 1895
HORACE E. HORTON	" 2, 1895	to	" 2, 1896
JOHN F. WALLACE	" 2, 1896	to	" 5, 1897
THOS. T. JOHNSTON	" 5, 1897	to	" 4, 1898
ALFRED NOBLE	" 4, 1898	to	" 3, 1899
ONWARD BATES	" 3, 1899	to	" 2, 1900
AMBROSE V. POWELL	" 2, 1900		

1st VICE-PRESIDENTS.

MOSES LANE	Aug. 3, 1880	to	Jan. 2, 1882
*DEWITT C. CREGIER	Jan. 2, 1882	to	" 9, 1883
S. S. GREELEY	" 9, 1883	to	" 15, 1884
ISHAM RANDOLPH	" 15, 1884	to	" 6, 1885
OCTAVE CHANUTE	" 6, 1885	to	" 5, 1886
C. H. HUDSON	" 5, 1886	to	" 4, 1887
L. E. COOLEY	" 4, 1887	to	" 3, 1888
JOHN W. WESTON	" 3, 1888	to	" 8, 1889
CHAS. MACRITCHIE	" 8, 1889	to	" 8, 1890
ROBERT A. SHAILER	" 8, 1890	to	" 7, 1891
JOHN F. WALLACE	" 7, 1891	to	" 6, 1892
E. C. CARTER	" 6, 1892	to	" 4, 1893
H. A. RUST	" 4, 1893	to	" 3, 1894
DANIEL W. MEAD	" 3, 1894	to	" 2, 1895
L. P. MOREHOUSE	" 2, 1895	to	" 2, 1896
THOS. T. JOHNSTON	" 2, 1896	to	" 5, 1897
ALFRED NOBLE	" 5, 1897	to	" 4, 1898

*Deceased.

James J. Reynolds	"	4, 1898	to "	3, 1899
Nelson O. Whitney	"	3, 1899	to "	2, 1900
Edward J. Blake	"	2, 1900		

2d VICE-PRESIDENTS.

*Dewitt C. Cregier	Aug.	3, 1880	to Jan.	2, 1882
Kirtland F. Booth	Jan.	2, 1882	to "	9, 1883
Itham Randolph	"	9, 1883	to "	15, 1884
Augustine W. Wright	"	15, 1884	to "	6, 1885
*Samuel McElroy	"	6, 1885	to "	5, 1886
D. J. Whittemore	"	5, 1886	to "	4, 1887
Ira O. Baker	"	4, 1887	to "	3, 1888
Octave Chanute	"	3, 1888	to "	8, 1889
*Samuel McElroy	"	8, 1889	to "	8, 1890
W. R. Northway	"	8, 1890	to "	7, 1891
W. O. Seymour	"	7, 1891	to "	6, 1892
Ira O. Baker	"	6, 1892	to "	4, 1893
Hiero B. Herr	"	4, 1893	to "	3, 1894
H. C. Draper	"	3, 1894	to "	2, 1895
Thos. T. Johnston	"	2, 1895	to "	2, 1896
Alfred Noble	"	2, 1896	to "	5, 1897
James J. Reynolds	"	5, 1897	to "	4, 1898
A. V. Powell	"	4, 1898	to "	3, 1899
T. L. Condron	"	3, 1899	to "	2, 1900
William H. Finley	"	2, 1900		

EXECUTIVE COMMITTEES.

W. H. Clark *Max Hjortsberg	June 14, 1869 to June 8, 1874.
H. W. S. Cleveland C. W. Durham	June 8, 1874 to June 15, 1875.
S. S. Greeley W. M. R. French	June 15, 1875 to June 17, 1878.
S. S. Greeley Benezette Williams	June 17, 1878 to Aug. 3, 1880.

TRUSTEES.

S. S. Greeley H. C. Nutt *R. J. McClure	Aug. 3, 1880 to Jan. 2, 1882.
S. S. Greeley *R. J. McClure W. S. McHarg	Jan. 2, 1882 to Jan. 9, 1883.
*R. J. McClure W. S. McHarg W. Sooy Smith	Jan. 9, 1883 to Jan. 15, 1884.

*Deceased.

W. S. McHarg W. Sooy Smith *R. J. McClure	Jan. 15, 1884 to Jan. 6, 1885.
W. Sooy Smith *R. J. McClure A. W. Wright	Jan. 6, 1885 to Jan. 5, 1886.
*R. J. McClure S. G. Artingstall *A. Gottlieb	Jan. 5, 1886 to Jan. 4, 1887.
S. G. Artingstall *A. Gottlieb H. A. Rust	Jan. 4, 1887 to Jan. 3, 1888.
*A. Gottlieb H. A. Rust O. B. Green	Jan. 3, 1888 to Jan. 8, 1889.
H. A. Rust O. B. Green Chas. Fitz-Simons	Jan. 8, 1889 to Jan. 8, 1890.
O. B. Green Chas. Fitz-Simons B. Williams	Jan. 8, 1890 to Jan. 7, 1891.
Chas. Fitz-Simons B. Williams O. Chanute	Jan. 7, 1891 to Jan. 6, 1892.
B. Williams O. Chanute C. L. Strobel	Jan. 6, 1892 to Jan. 4, 1893.
O. Chanute C. L. Strobel Geo. S. Morison	Jan. 4, 1893 to Jan. 3, 1894.
C. L. Strobel Geo. S. Morison Robt. W. Hunt	Jan. 3, 1894 to Jan. 2, 1895.
Geo. S. Morison Robt. W. Hunt G. A. M. Liljencrantz	Jan. 2, 1895 to Jan. 2, 1896.
Robt. W. Hunt G. A. M. Liljencrantz Horace E. Horton	Jan. 2, 1896 to Jan. 5, 1897.
G. A. M. Liljencrantz Horace E. Horton *Ferd. Hall	Jan. 5, 1897 to Jan. 4, 1898.
Horace E. Horton *Ferd. Hall Geo. P. Nichols	Jan. 4, 1898 to Jan. 3, 1899.

*Deceased.

*Ferd. Hall	Jan. 3, 1899 to Jan. 2, 1900.
Geo. P. Nichols	
August Ziesing	
Geo. P. Nichols	Jan. 2, 1900.
August Ziesing	
Bion J. Arnold	

SECRETARIES.

L. P. Morehouse	June 14, 1869 to Jan. 3, 1888.
Lyman E. Cooley	Jan. 3, 1888 to " 8, 1889.
John W. Weston	" 8, 1889 to " 3, 1894.
Thomas Appleton	" 3, 1894 to " 2, 1895.
Charles J. Roney	" 2, 1895 to Mar. 4, 1896.
Henry Goldmark	Mar. 4, 1896 to Aug. 5, 1896.
Nelson L. Litten	Aug. 5, 1896

TREASURERS.

L. P. Morehouse	June 14, 1869 to Aug. 3, 1880.
Charles Fitz-Simons	Aug. 3, 1880 to Jan. 4, 1887.
A. V. Powell	Jan. 4, 1887 to " 3, 1888.
W. S. Bates	" 3, 1888 to " 8, 1889.
H. W. Parkhurst	" 8, 1889 to " 8, 1890.
John W. Weston	" 8, 1890 to " 4, 1893.
*Edwin G. Nourse	" 4, 1893 to " 3, 1894.
*David L. Barnes	" 3, 1894 to " 2, 1896.
Emil Gerber	" 2, 1896 to " 4, 1898.
C. W. Melcher	" 4, 1898 to " 2, 1900.
Ralph Modjeski	" 2, 1900

LIBRARIANS.

John W. Weston	Aug. 3, 1880 to Jan. 9, 1883.
G. A. M. Liljencrantz	Jan. 9, 1883 to " 8, 1890.
John W. Weston	" 8, 1890 to " 3. 1894.
Thomas Appleton	" 3, 1894 to " 2, 1895.
Chas. J. Roney	" 2, 1895 to Mar. 4, 1896.
Nelson L. Litten	" 12, 1898

*Deceased.

DECEASED MEMBERS.*

Name.	Date of Death.
Adler, Dankmar	April 16, 1900.
Baker, William L	May 28, 1888.
Barnes, David Leonard	December 15, 1896.
Booth, Kirtland Farnum	March 23, 1892.
Bryson, Wm	October 26, 1876.
Bullock, Milan C	January 12, 1899.
Card, Joseph P	October 22, 1894.
Cheney, Orlando H	April 13, 1894.
Chesbrough, Ellis S	August 18, 1886.
Chesbrough, I. C	January 28, 1893.
Clarke, William Hull	1879.
Colborne, B. B	1893.
Cregier, DeWitt C	November 9, 1898.
DeHart, Norwood	May 11, 1899.
Farquar, Col. F. U	July 3, 1883.
Ferris G. W. G.	November 22, 1896.
Gardner, H. A	1875.
Gottlieb, Abraham	February 9, 1894.
Hall, Ferdinand	November 22, 1899.
Hammett, Wm. A	September , 1895.
Higginson, Charles M	May 6, 1899.
Hjortsberg, Maximillian	May 16, 1880.
Lake, George Bert	April 27, 1884.
Lane, Moses	January 25, 1882.
Latimer, Charles	March 25, 1888.
Lincoln, Isaac	March 13, 1894.
Lotz, William Herman	January 31, 1894.
Mason, Col. Eddy D	1875.
Mason, Roswell B	January 1, 1892.
McClure, Robert J	March 17, 1899.
McElroy, Samuel	December 10, 1898.
Neu, Peter W	February 4, 1899.
Nourse, Edwin G	December 8, 1897.
Perkins, A. H	February 24, 1897.
Phillips, Jonathan	1892.
Poe, Orlando M	October 2, 1895.
Pope, Willard Smith	October 10, 1895.
Porter, J. A	June , 1885.
Scherzer, William	July 20, 1893.
Schuyler, Howard	December 3, 1883.
Smith, Lyman	July 9, 1898.
Smith, Warren Collier	March 29, 1895.
Talcott, Edward B	February , 1886.
Taylor, William E	February 4, 1883.
Turknett, Robert G	July , 1889.
Watson, Joseph A	February 5, 1893.
Whitton, A. D	1892.
Wolcott, Alexander	August 11, 1884.

*This list is incomplete. Members are requested to advise the Secretary of the name and date of the death of any deceased member not included in this list.

LIBRARY AND READING ROOM.

Library.

The Library contains 3,500 books and about 2,000 pamphlets on technical and allied subjects, classified and catalogued, which are free to any one desiring to consult them. Of these there are, complete to date.

Transactions and Minutes of the Proceedings of the Institution of Civil Engineers, London, Eng.,

Transactions of the American Society of Civil Engineers,

Transactions of the American Society of Mechanical Engineers,

Transactions of the American Institute of Mining Engineers,

Journal of the Association of Engineering Societies, and transactions of other societies, also bound volumes of the leading publications in all branches of engineering.

Members and friends of the Society who are interested in extending a knowledge of technical information, especially so far as it relates to civil, mechanical, mining and electrical engineering, are invited to co-operate in enlarging this library. Donations of books, pamphlets and periodicals of any date will be acceptable, and due acknowledgment will be made in the Journal of the Society.

The New Reading Room is completed and open to members and their friends. It is furnished with a large oak center table, writing desks supplied with writing materials, comfortable easy chairs, a large Davenport couch, electric lights, and the floor is covered with a handsome rug. It will be a convenient and pleasant place for members to meet friends, to spend leisure moments in looking over the latest engineering publications or to consult the books of the Library.

In addition to the books and pamphlets there are in the Library periodicals, magazines and various society transactions regularly received, a list of which follows:

FOREIGN LIST.

Archiv fur Eisenbahnwesen, Berlin, Germany.
Association des Ingenieurs, Gand, Belgium.
Automotor & Horseless Vehicle Journal, London, England.
Colliery Guardian, London, England.
Conservatoire National des Arts et Metiers, Paris, France.
Electrical Engineer, London, Eng.
Electrical Review, London, England.
Electricity, London, England.
Engineer, The, London, England.
Engineering, London, England.
Engineering Times, London.
Feilden's Magazine, London.
Imperial Technical School, Moscow, Russia.
Indian Engineer Co., The, Ltd., Calcutta, India.
Indian Engineering, Calcutta, India.

FOREIGN LIST—Continued.

Industries and Iron, London, England.
Institution of Civil Engineers, Proceedings, London, England.
Institution of Mechanical Engineers, Transaction of, London, England.
Institution of Naval Architects, Transaction of, London, England.
Iron & Coal Trade Review, The, London, England.
Iron & Steel Trades Journal, London, Eng.
Journal of the Institution of Electrical Engineers, London, England.
Journal of the Society of Arts, London.
Konigliche Mechanisch-Techniche Versuch,Anstalt, Charlottenburg, Berlin, Germany.
Locomotive Magazine, London, Eng.
Mechanical Engineer, The, Manchester, England.
Mechanical World, Manchester, England.
Mining Journal, London, England.
Mining World, London, England.
N. E. Coast Institute of Engineers & Shipbuilders, New Castle-on-Tyne, England.
North of England Institute of Mining & Mechanical Engineers, New Castle-on-Tyne, England.
Plumber & Decorator, London, England.
Ponts et Chaussees, Paris, France.
Practical Engineer, Manchester, England.
Railway Engineer, The, London, England.
Revue Technique, Paris, France.
Revue Practique de L'Electricity, Paris, France.
Societe des Ingenieurs Civils de France, Paris, France.
Societe Industrielle de Muhlhouse, Muhlhouse, Alsace, Germany.
Societe Internationale des Electriciens, Bulletin de la, Paris, France.
Teknisk Tidskrift, Stockholm, Sweden.
Thonindustrie-Zeitung, Berlin, Germany.
Trade Journals' Review, Manchester, England.
Zeitschrift der Centralverband des Dampfkessel Ueberwachungs Verein, Breslau, Germany.

DOMESTIC LIST.

CHICAGO.

American Contractor.
American Miller.
Armour Institute, Catalog.
Black Diamond.
Board of Trade, Reports.
Bridges and Frame Structures.
Brick.
Cement & Engineering News.
Construction News Co.
Iron & Steel.
Inland Architect.
Irrigation Age.
Lewis Institute, Catalog.
Master Car Builders' Association.
Modern Machinery.
Monist.
National Builder.
National Engineer.
Open Court, The.
Proceedings Board of Trustees Sanitary District.
Railway Age.
Railway Master Mechanic.
Railway Review.
Roadmaster & Foreman.
Street Railway Review.
Telephone Magazine.
Western Electrician.
Western Foundryman.
Western Railway Club.

OTHER CITIES.

Academy of Natural Sciences, Philadelphia, Pa.
Age of Steel, St. Louis, Mo.
American Architect & Building News Boston, Mass.
American Electrician Co., New York.
American Engineer & Railroad Journal, New York City.
American Geographical Society, Bulletin of, New York City.
American Geologist, Minneapolis, Minn.
American Institute of Electrical Engineers, New York City.
American Institute of Mining Engineers, New York City.
American Journal of Science, New Haven, Conn.
American Machinist, New York City.
American Philosophical Society, Philadelphia, Pa.

DOMESTIC LIST—Continued.

American Society of Civil Engineers, Transactions of, New York City.
American Society of Naval Engineers, Journal of, Washington, D. C.
American Water Works Association, New York.
Annals American Academy Political and Social Science, Philadelphia, Pa.
Architects' & Builders' Magazine, New York.
Association of Civil Engineers, Ithaca, New York.
Association of Engineering Societies, Philadelphia, Pa.
Association of Ontario Land Surveyors, Toronto, Canada.
Boston Journal of Commerce & Textile Industries.
Brickbuilder, Boston, Mass.
California Architect & Building News, San Francisco, Cal.
Canadian Engineer, Toronto, Can.
Canadian Society of Civil Engineers, Montreal, Que.
Cassier's Magazine, New York City.
Central Railway Club, New York City.
Clay Worker, Indianapolis. Ind.
Colorado Scientific Society. Denver, Colo.
Compressed Air, New York City.
Cordage Trades Journal, New York City.
Electrical Age, New York City.
Electrical Review, New York City.
Electrical World & Electrical Engineer, New York City.
Electricity, New York City.
Engineering & Mining Journal, New York City.
Engineer, The, New York City.
Engineering Magazine, New York,
Engineering Mechanics, Philadelphia, Pa.
Engineering News, New York City.
Engineering Record, New York City.
Engineering Society, School of Practical Science, Toronto, Canada.
Engineering Society of Western Pennsylvania, Fittsbugh, Pa.
Engineers' Club, Philadelphia.
Engineers' Club, St. Louis, Mo.
Engineers' Society of Western New York, Buffalo, N. Y.
Franklin Institute, Philadelphia, Pa.
Heating & Ventilation, New York City.
Illinois Society of Engineers & Surveyors, Peoria, Ill.
Indiana Engineering Society, Remington, Ind.
Inventive Age, Washington, D. C.
Iron Age, New York City.
Iron Trade Review, Cleveland, Ohio.
Journal of the Military Service Institution, Governors' Island, New York.
Kansas University Quarterly, Lawrence, Kansas.
L. A. W. Bulletin. Boston, Mass.
Literary Digest, New York.
Locomotive, The, Hartford, Conn.
Machinery, New York City.
Manufacturers' Record, Baltimore Md.
Marine Engineering, New York City.
Marine Review, Cleveland, Ohio.
Massachusetts Institute of Technology, Boston, Mass.
Metal Worker, New York City.
Michigan Agricultural College, Agricultural P. O., Ingham Co., Mich.
Michigan Engineering Society, Climax, Mich.
Michigan Mining School, Houghton, Mich.
Mines & Minerals, Scranton, Pa.
Mining Review, Ottawa, Canada.
Municipal & Railway Record, New York City.
Municipal Engineering, Indianapolis, Ind
New England Cotton Manufacturers' Association. Boston, Mass.
New England Railway Club, Springfield, Mass.
New England Water Works Association, Boston, Mass.
New Hampshire Agricultural College, Durham. N. H.
New York Railroad Club, Brooklyn, N. Y
New York State Board of Health, Albany, N. Y.
North-West Railway Club, Minneapolis, Minn.
Nova Scotia Institute of Science, Halifax, Nova Scotia.
Ohio Sanitary Bulletin, Columbus, O.
Patent Office, Department of the Interior, Washington, D. C.
Philadelphia Museum, Philadelphia, Pa
Physical Review, Cornell University, Ithaca, N. Y.
Power, New York City.
Proceedings United States Naval Institute, Washington, D. C.
Pratt Institute Monthly, Brooklyn, N. Y.
Progressive Age, New York City

DOMESTIC LIST—Continued.

Public Opinion, New York.
Railroad Gazette, New York City.
Railroad Car Journal, New York City.
Railroad Men, New York City.
Rose Polytechnic Institute, Terre Haute, Ind.
Rennssalaer Polytechnic Institute, Troy, N. Y.
Sanitarian, New York.
Scientific American, New York City.
Smithsonian Institution, Washington, D. C.
Steam Engineering, New York.
Stevens Indicator, Hoboken, New Jersey.
Stone, New York City.
Street Railway Journal, New York City.
Tin & Terne, Pittsburg, Pa.
Technical Society of Pacific Coast, San Francisco, Cal.
Technology Review, The, Boston, Mass.
Tradesman Publishing Co., Chattanooga, Tenn.
Transit, The, Iowa City, Iowa.
United States Artillery Journal, Fortress Monroe, Va.
Yale Scientific Monthly, Yale University.
Water & Gas Review, New York City.